ABSTRACT

Title of Thesis: DEVELOPMENT OF A FRINGE PARKING MODEL

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Fringe parking is a parking management tool used by cities to provide additional parking on the outskirts of the central business district to achieve the goals of reducing downtown congestion, eliminating the need to construct downtown parking facilities and/or providing travelers with a lower cost parking option. There is limited research on forecasting techniques with fringe parking as a separate mode within a regional mode choice model. In this research, fringe parking is incorporated as a top-level choice inside the existing MNL model for the Hampton Roads area, which includes Norfolk, Virginia. The model is calibrated to existing conditions and sensitivity tests conducted show how the model can be used as an analysis tool for urban planners and policymakers.

DEVELOPMENT OF A FRINGE PARKING MODEL

by

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To my wonderful family. I could not have done this without your support.

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Chapter One: Introduction

Fringe parking or peripheral parking is the practice of utilizing parking areas on the outskirts of the central business district (CBD). This practice differs from traditional park-and-ride usage in that the majority of the trip length is made by automobile. Then the user travels to his or her final destination by an egress mode such as walking, transit, or dedicated shuttle.

Fringe parking is an important policy tool for cities. Fringe parking allows cities to increase the number of available parking spaces for the downtown area without using valuable land in the CBD core for parking lots or structures. Encouraging fringe parking can also reduce downtown automobile congestion and the time that drivers spend waiting in traffic, thus reducing air pollution. Some cities that have fringe parking programs include Pittsburgh, Pennsylvania; St. Paul, Minnesota; San Jose, California; and Norfolk, Virginia.

There is a fair amount of literature studying fringe parking; however, there is limited research on forecasting demand for fringe parking. Fringe parking is not usually identified as a separate mode from auto modes or transit park-and-ride modes, but its unique characteristics suggest that individuals who use fringe parking weigh decision-making criteria differently. Because of this, cities that have strong fringe parking activity or wish to study potential fringe parking sites may wish to consider modeling fringe parking trips within the regional travel demand model.

There are several benefits to having fringe parking as a mode choice in the regional model rather than estimating demand through an “off-model” procedure. The first is that fringe parking competes directly with other available modes. With fringe parking market integrated into the overall regional model it is subject to the mode choice model decisions. This will show which trips are most likely to shift to fringe parking if it is available. Another benefit to modeling fringe parking is that these trips can be accurately reported in the regional VMT and air quality totals. Finally, for cities studying proposed transit service, such as a light rail transit line, which would serve a fringe parking lot, the impact on ridership by fringe parking patrons can be forecasted.

There are two main goals for this research. The first is to develop a fringe parking nest within the existing Hampton Roads Transit mode choice model (which includes Norfolk Virginia) to incorporate fringe parking as a top-level mode choice. The model will be based on a methodology developed for the Southwestern Pennsylvania Commission (including the Pittsburgh area) model in 2003 by AECOM Consult, Inc (AECOM, 2003).

The City of Norfolk has a formal fringe parking program operated by the Norfolk Division of Parking. This market is defined as those people who work in the downtown core but who drive to a parking location on the edges of downtown (specifically, Lot 39, Harrison Opera House and Harbor Park), and use either the NET (a downtown circulator), a shuttle bus (provided by certain employers for their employees) or walk to their final destination. In order to incorporate fringe parking as a choice in the Hampton Roads regional model, the nesting structure was changed to make fringe parking a top-level choice, thus creating the choice between driving, transit or fringe parking. Data were collected from Norfolk's three existing fringe parking lots. The data included the mode of egress for parkers and the origin jurisdiction (based on the vehicle locality sticker). The data were inflated using information from the Norfolk Division of Parking to obtain control totals. The model was then calibrated to those control totals.

The second and ultimate goal of this research is to show that this model can be a tool that planners and policymakers can use to study the effect of cost and service variables on fringe parking usage, forecast future demand and make effective planning decisions. To show some potential uses of the model, it was used to conduct sensitivity tests. These tests show the effect of different variables (fringe parking lot cost, downtown parking cost and transit egress frequency) on individuals' decisions to use fringe parking, and on the mode split of the region as a whole.

Chapter Two: Literature Review

What is Fringe Parking?

The term “fringe parking” refers to off-street parking facilities such as parking lots or garages on the outskirts of the downtown business core. The ‘fringe’ being referred to varies in size and could describe parking just blocks from the CBD or parking well outside of walking distance where patrons rely on mass transit to complete their trip (Lovejoy, 1947). Fringe parking differs from park-and-ride parking because the majority of the length of the fringe parking trip is made by automobile.

For purposes reviewing literature, ‘fringe parking’ was defined as parking on the immediate fringes of the downtown CBD area, which is admittedly a very subjective definition. Facilities that are within approximately one mile from the CBD, a long walking distance, were the focus of this research. However, due to the availability of existing research, comparisons were made to parking facilities situated outside of this definition (such as traditional park-and-ride) when relevant.

There are several characteristics that are important to both fringe parking users and parking policy makers. Lot location is important for a successful fringe parking lot. The fringe parking lot should be located within a high-density commuter corridor and “situated prior to those points where road congestion begins” in order to have a benefit to the those parking in the lot and the regional transportation system (Wester and Demetsky, 1979). The lot location should ideally be located where land is less valuable than in the CBD. The daily parking cost for users of the lot should be competitive with downtown parking so that the cost savings outweighs the additional time and inconvenience for parkers. The egress mode options between the fringe parking lot and the CBD need to be safe, frequent and reliable.

There are many potential benefits for cities that incorporate fringe parking into their parking management plans. Fringe parking can reduce the number of vehicles and congestion in the CBD area. The reduction in congestion can contribute to reduction in air pollution. Alternative parking, such as fringe parking, can reduce the need for the construction and maintenance of costly CBD parking structures.

History of Fringe Parking

Fringe parking began as a solution to an "accessibility problem" caused by automobile traffic congestion in the downtown CBD area (Lovejoy, 1947). The downtown congestion problem was viewed as a serious problem that was "generally ascribed as the cause of the economic deterioration of the centers of our cities" (Hughes, 1948). City planners aimed to stop the trend towards decentralization that began as a result.

Some of the first cities with fringe parking facilities included Philadelphia, Cleveland, St. Louis, and Baltimore as early as the mid-1940's. These cities fit the primary requirements for viable fringe parking facilities, which included having a well-developed mass transit system and a centralized downtown development of retail, business and entertainment (Lovejoy, 1947). St. Louis, with a 1940 population of over 1.3 million people, had developed a successful fringe parking system with five lots that ranged from 0.25 to 1.50 miles from the CBD with lot locations in all directions. Publicly run buses served these lots and the downtown area (Lovejoy, 1949).

The Baltimore Transit Company, in cooperation with the city, opened a fringe parking lot in 1946 approximately 0.75 miles north of the shopping district and a mile from the business center of the CBD. The 207 spaces were quickly filled to capacity with a daily average of 270 vehicles (accounting for turnover) just months after opening. Riders were attracted by frequent service (5 minute peak headway, 7.5 minute off-peak headway) provided by a short bus line which served the lot, the shopping and financial centers and the civic center. While the fringe parking lot attracted more parkers than there were spaces, "such a small operation could not give a reliable indication of bus revenue and costs" (Lovejoy, 1948). The transit company was not making a profit by operating the fringe parking lot and shuttle. As for the goal of relieving downtown congestion, the number of parkers attracted to the fringe lot was not enough to make a notable reduction in downtown traffic.

Many cities ended early fringe parking efforts that were deemed unsuccessful. That is, fringe parking combined with transit was not substantially more attractive to travelers than driving to the CBD and/or the cost of operating the lot and providing transit could not be covered by revenue generated from the lot. In a report (Lovejoy, 1949) examining these cities, including Hartford, Connecticut; Norfolk and Richmond, Virginia; Denver; and Atlanta, it was found that these cities likely failed to attract travelers for similar reasons. All of these cities had populations, at the time, of less than 350,000 people and had not yet decentralized to the point where trips were long enough to make using two modes of travel attractive to travelers (Lovejoy, 1949). Other cities saw fringe parking efforts fail for different reasons. Pittsburgh abandoned an early fringe parking lot that was inconveniently located across a river from the downtown.

Washington, DC ended shuttle bus service when the fare for riding the bus could not compete with relatively low CBD parking costs (Lovejoy, 1949).

As these cities continued to develop and grow in population and physical size, many of these cities resumed fringe parking plans, and cities with existing fringe parking continued to improve and institutionalize these facilities. By institutionalizing fringe parking facilities, travelers were discouraged from parking on residential streets and parking demand was centralized making dedicated bus service, and even rail service, more feasible (Ellis, 1971). Currently, cities throughout the country are studying and using fringe parking strategies as part of city parking policies.

CBD Parking Management Policies

Downtown parking management is important for relieving downtown congestion and improving mobility. There is a great deal of debate between planners, engineers, city managers, businesses, and the general public on what parking management measures are most appropriate (Parker and Demetsky, 1980). Cities have the difficult task of designing parking management strategies for a wide array of trip types – commuters who park all day during normal business hours, people making necessary daytime short-term trips, and people making discretionary short-term trips. Not all of these trips would be good candidates for fringe parking. Fringe parking is most likely to attract commuters who are parking for several hours. The lure of fringe parking for commuters may be a balance between cost savings (as opposed to parking in the CBD) and ease of accessibility to the users' vehicles (as opposed to park-and-ride).

Cities that would benefit from implementing fringe parking may have some or all of the following criteria, according to Wester and Demetsky (1979): limited parking facilities in the CBD, significant traffic congestion and "excessive trip-making costs" which may include high parking costs and tolls.

A TCRP report on parking management and supply (TCRP, 2003) discussed the potential for using fringe or peripheral parking as a parking supply management technique. The report suggested that fringe parking lots located far enough from the CBD to be inexpensively priced while still being close enough for people to walk to take a short transit ride to their final destination could intercept trips destined for already congested downtown streets. The TCRP report cited a study that looked at several fringe parking demonstration projects in the late 1970s and early 1980s in cities including Cincinnati, Cleveland, Fort Worth, Albany, Atlanta, San Diego, Pittsburgh and the District of Columbia. Most of the facilities were located within a mile of the CBD, with a few located up to three miles away. The majority of the lots were served by shuttle service with headways of ten minutes or less. The study found that most people chose walking as their mode between the fringe parking lot and their final destination. As a parking management technique, most of the projects were successful. The study revealed shifts in parking demand from the CBD to the fringe lots. As a result, traffic was diverted from the CBD core. The fringe lots were not a success in all cities. Notably, the TCRP report showed that in Atlanta, San Diego and Baltimore (in another study), fringe parking was not successful in attracting users because there was not a significant cost savings over downtown parking.

The success of a fringe parking lot should be directly related to the goals for a particular city. For cities, fringe parking lots may not have to be near capacity in order to consider the lot to be successful. From a city planner's perspective, a successful fringe parking lot could help alleviate downtown congestion, reduce the need for the construction of additional parking structures, make more parking spaces available for short-term trips or provide travelers with a lower cost parking option. These goals; however, may be at odds with the cost of providing fringe parking. Costs of operating the lots or dedicated shuttles serving the lots may prove to be prohibitive if the parking lot does not generate enough revenue to cover those costs.

While the focus of this research is fringe parking, it is important to understand where fringe parking may fit within the greater spectrum of parking management policies. McShane and Meyer (1982) studied how downtown parking management policies could be focused in such a way as to work in conjunction with other urban planning objectives. Some of these goals included maintaining or developing a strong economic base in the CBD, making the best use of existing infrastructure, improving accessibility, distributing benefits in an equitable manner, meeting environmental standards, and enhancing the overall beauty of the city. The authors differentiated between "parking policy," which is a group of programs designed to meet a goal such as one of the aforementioned, and "parking strategy," which is a single specific action such as increasing parking taxes. The study examined four different parking strategy categories: "control of aggregate supply," "control of parking access," "control of spatial location" and "control of parking price." The development of fringe parking facilities falls under the "control of spatial location" category.

Some of the specific parking strategies that were available to planners were regulating the number of spaces required per square foot of commercial space, zoning to prohibit parking on land not already developed as parking facilities, residential parking permit programs, time-limited meters in commercial areas, parking taxes and regulated rate structures.

According to Shiftan and Burd-Eden (2001), “parking policy is one of the most powerful means to manage travel demand and traffic in city centers.” The objective of parking management policies is to improve mobility and reduce congestion in the CBD by encouraging the use of public transportation and still making the CBD an attractive destination. A balance has to be found to implement successful parking strategies without driving business and retail out of the CBD to the suburbs where parking is more abundant.

Shiftan and Burd-Eden (2001) used the results of a survey asking both work and non-work drivers how their mode choice might be altered if the time required to find a parking space increased. The respondents were asked how they would change their trip if the time required to find a parking space increased by 10, 15, or 20 minutes or if the hourly cost of parking increased. The choices included not changing their behavior, shifting to another mode such a transit or taxi, changing the time or destination of their trip, or canceling the trip altogether. These survey results were used to develop a binary logit, a multinomial logit (MNL) model, and a nested logit model to predict a users response to changes in parking policy.

It was found that workers are less likely to change their travel behavior than non-work travelers in response to changes in parking policy. The resulting coefficients for parking cost and parking search time were much higher for non-workers than for workers. The model showed that travelers were more likely to change the mode or time of day of their trip rather than cancel the trip or change their destination. Those making non-work trips were more likely to alter their travel (using any of the six possible behavior changes) than those making work trips (who, if making changes, would be more prone to changing the mode of transportation or time of day). For both work and non-work trips, the longer the traveler planed to spend in the city, the less likely he or she was to change the destination of the trip or cancel the trip. The authors found that none of the three nested model structures developed added significant additional insight into travel behavior.

Shiftan and Burd-Eden (2001) found that parking management techniques do not seem to have a negative effect on work trips or other trips where the length of the visit is comparably long. They cautioned that the parking management techniques can adversely affect shorter trips, such as shopping trips, which could have a negative impact on the vitality of the CBD.

One of the parking strategies, regulating the supply of downtown parking, has been shown to be an effective parking policy strategy. Morrall and Bolger (1996) examined the relationship between downtown parking availability and park-and-ride/transit usage. In this study, the authors compared the effectiveness of the parking policies for increasing transit usage and decreasing CBD congestion in Calgary, Canada to other cities.

Two of the key measures of a city's parking policy are the number of parking spaces (all-day, rather than short-term) per CBD employee and the number of park-and-ride spaces per CBD employee. It was noted by the authors that the greater number of CBD employees a city has, the smaller the all-day parking space to employee ratio is; however there is no clear relationship between the number of park-and-ride spaces and the number of CBD employees. Although each of the cities examined has legislation setting a maximum limit on the number of downtown parking spaces, five of the six cities had more parking than allowed at the time during which Morrall and Bolger (1996) were conducting the study.

The study supports the strong relationship between the choice to use transit and downtown parking supply. Cities with the most successful downtown parking policies are aided by reliable public transit, compact downtown areas, strong enforcement of parking policies and support for new policies.

While there are many good parking management policies, there can also be poor ones. Extreme policies which prohibit automobiles from entering particular areas of the CBD or policies which prohibit construction of off-street parking can have a negative effect by stunting employment growth. A lack of employment in downtown can have a negative impact on the growth of cultural and tourism activities (Walker and Cummings, 1972).

The Effects of Parking Cost on Mode Choice

The most influential factor in deciding whether to park at a destination is the cost (Fontaine, 2003). Swanson (2004) also studied Calgary (and five other Canadian cities) to show the relationship between CBD employment and parking supply on parking rates. Swanson argued that CBD vitality is a major factor in determining the prevailing parking rate. A thriving downtown is likely to have a high employment density, which would increase the demand for parking. Swanson concluded that increasing employment will increase the demand for parking and without an increase in available parking, the cost of parking will rise.

In the United States, employer-paid parking is a fringe benefit offered by a vast majority of employers. Employer-provided parking does little to encourage transit or ride share modes and it contributes to congestion and air pollution. In 1990, 91 percent of commute trips in the United States were made by automobile and 95 percent of those trips did not incur a parking charge (Shoup, 1997). Williams (1992) cited several reasons why employers may provide free or subsidized parking for their employees, such as the notion that employees with available parking are more able to work additional hours, and fringe benefits do not have to be accounted for in an employee's base salary when calculating raises. While this benefit is very popular among employees, it provides incentive for people to choose single occupancy vehicles as their transportation mode of choice.

In a study completed by Willson and Shoup (1990), the authors found that employer-paid parking "strongly works at cross purposes with public policies designed to reduce traffic congestion, energy consumption, and air pollution." Employer-paid parking encourages employees to drive solo while discouraging ridesharing, carpooling and transit usage. The effects of employer-paid parking extend to increasing air pollution, traffic congestion and gas consumption.

Willson and Shoup (1990) used three different methods to analyze previously completed studies to measure the effect of employer parking subsidies on commuter mode choice. The first method to measure the effects of employer-paid parking was a mode share comparison between employees whose employers pay for parking and those employees whose employers do not pay for parking. The second method determined the number of automobiles used per every 100 employees. The third and final method were a calculation of the "parking price elasticity of demand for solo driving." This method showed the change in the percentage of solo drivers with respect to a one percent change in the cost of parking.

The studies that Willson and Shoup (1990) reviewed fall into two categories. The first was a "before/after" analysis where employees react to a change (either an addition or a removal) of the employer parking subsidy and the second was a "with/without" where the parking subsidy situation does not change during the course of the study. Most of the case studies came from southern California, but there were also studies from Toronto, Washington, D.C. and Seattle. All of the studies supported the theory that reducing or ending employer parking subsidies reduces the mode share of single occupancy vehicles.

Willson and Shoup (1990) reviewed four "before/after" studies. In all four of these cases, transit was a viable option for many employees. In all of the cases, when employer parking subsidies decreased, the percentage of single occupancy vehicles dropped, as did the number of autos per 100 employees. It was found that deceasing parking subsidies decreased the number of solo drivers anywhere from 19 to 81 percent and reduced the number of autos driven for commuting purposes between 15 and 38 percent. A case near downtown Los Angeles showed that many employees reacted to a reduction in parking subsidies by joining car or van pools, providing the employer continued to provide rideshare benefits. In the three "with/without" studies the authors analyzed, they found results that supported the theory of a greater mode share for single occupancy vehicles when employers provide parking subsidies.

Willson and Shoup (1990) found that overall, decreasing parking subsidies in the before/after situation leads to a decrease in solo driving. This result could be seen across all four case studies despite differences in area (urban vs. suburban), type of employer and type of employee jobs. While this study did not consider fringe parking as a non-solo driving alternative, it did show the strong influence that parking costs have on a commuter's mode choice.

Williams (1992) studied parking in the Washington, D.C metropolitan area to determine the relationship between employee parking costs and modal choice. The six month study consisted of collecting parking fee data from both private and public parking facilities, surveying private employers to gather a picture of the number of employers offering parking subsidies and the amount of those subsidies, and finally estimating the number of cars parking by using the regional travel model.

The study examined three different types of parking fees. The first was a "pervasive parking charge," which is prevalent in high density, downtown CBD areas such as downtown Washington, D.C., Bethesda and Arlington. In these areas, almost all parking had a fee and drivers are subjected to that fee unless employers have parking subsidy programs. Other areas had "scattered parking charges." These areas had pockets of dense commercial development with some parking facilities charging a fee. The third type of parking was free parking, which was found in less dense areas such as strip malls or office park developments. Williams (1992) found that "employment densities and transit usage correlate well with parking cost." Furthermore, in locations where parking is free or inexpensive and ample, employees were more likely to drive, in contrast to locations where parking was expensive and/or scarce where people were more likely to commute by other means.

In areas with pervasive parking fees, employers could choose to provide parking subsidies. Two possibilities include increasing an employee's salary to cover parking costs and providing free parking to employees. Williams (1992) found that in the central business district, 38 percent of drivers received free parking while in the immediate outlying area, 67 percent of drivers parked for free. In the entire region, it was estimated that only 18 percent of drivers pay for parking (at either the full or a discounted rate) while the remaining 82 percent parked for free.

Gillen (1977) examined the effects of a change in parking fee on mode choice in urban areas. Unlike the two previous studies discussed, this study focused on household decisions based on income class. The study had three goals: to characterize the parking cost variable in order to incorporate it into the mode choice model, to "calculate the microelasticity of mode choice with respect to parking costs," and to estimate the effect that changes in the individual characteristics have on the modal choices of the population as a whole.

Gillen (1977) used a binary choice model to determine the household choice between automobile or public transit with the goal of maximizing utility. In this study parking was "defined as a commodity which is complementary to automobile trips." This differed from other previous studies that add parking costs to automobile driving costs. Each parking lot was treated as a unique entity with its own unique parking cost and time. Gillen (1977) found that in this model "changes in relative fares…will have little effect on the mode for the work trip." He found that those with higher incomes are more likely to park closer to their destination while those who are more likely to be affected by a change in parking costs are those already parking farther away from their destination. From a policy standpoint, Gillen stated that changes in parking fees result in a "simple relocation to substitute parking areas" rather than a shift to a transit mode. The results of this study suggest that CBD parking pricing strategies could be implemented to encourage fringe parking, assuming that there is good accessibility to the fringe parking lot.

Even though drivers who would shift from employer-paid parking to fringe parking would still likely be solo drivers, there would be a reduction in CBD congestion with fewer drivers entering the CBD area. There would likely not be a drastic reduction in the regional VMT (vehicle miles traveled) even with an extensive fringe parking system. Fringe parking requires that the user travels the majority of the distance to his or her destination by car.

Who Uses Fringe Parking?

Fringe parking is an option for those individuals who are willing to trade the convenience of on-site parking for reduced cost parking (TCRP, 2003). These trips are more likely to be commuter trips, rather than short-term trips like shopping or business-related trips.

Foote (2000) analyzed a 1998 Chicago Transit Authority (CTA) park-and-ride user survey to determine the characteristics of a park-and-ride facility that make it attractive to current users and could make it attractive to future users. The results of this study allowed CTA to determine parking locations that were candidates for capacity or service expansion.

The survey was distributed at the 15 existing park-and-ride lots mainly during the morning peak period, with some also distributed during the afternoon peak period and some were left on windshields during the mid-day to account for users who did not arrive or leave during one of the peak periods. In analyzing the results of the survey, Foote found that a majority of park-and-ride lot users were traveling to or from work, which indicates that a person's employment stability as well as the parking benefits provided by the employer have a strong impact on whether a person uses a park-and-ride lot. The survey results indicated that park-and-ride lots are used more by women than men and compared to CTA ridership as a whole, more park-and-ride users are white and on average have a higher household income. The race and income findings were not surprising due to the locations of most park-and-ride lots.

There were some significant results of this study from a planner's perspective. The first was the potential revenue that can be generated from park-and-ride patrons. It was estimated that the 5,100 CTA park-and-ride users could generate a minimum of $23,000 weekly based on the average user costs for parking and the subsequent transit trip and the average number of days each week that users parked in the lots. Furthermore, the park-and-ride facilities attracted significantly more new users to rail rather than those who previously took the bus to a rail station, which indicates that there would likely be only a small reduction in CTA transit boardings by actively promoting CTA park-and-ride lots.

The survey responses when users were asked the most important reason for choosing to use a CTA park-and-ride lot provided the most interesting information for planning successful fringe parking lots. Over thirty percent of those surveyed felt that using a park-and-ride lot was the fastest way to make their trip, followed by 24.1 percent that disliked driving and 20.7 percent who felt that parking costs at their destination were too high. This third group of riders is an important group for planners to consider. Foote estimated that the majority of CTA park-and-ride lot users pay between $4.50 and $4.75 each day for parking and a roundtrip ride to downtown (less for those who use weekly or monthly passes) compared to the average destination parking cost of $10.29.

Foote (2000) summarized that based on the results of the survey, the most important aspect of successful park-and-ride usage is customer loyalty resulting from customer satisfaction. Despite the differences between fringe parking and park-and-ride, there is valuable information from this study that would be applicable to fringe parking planning. The survey results cited travel time as the largest determining factor for choosing to use park-and-ride. If fringe parking were available, and would similarly provide the shortest travel time (by being easily accessible and having frequent and reliable egress options) compared to driving in a congested CBD area, then fringe parking would be an attractive option for commuters. Cost was another major factor in the decision to park-and-ride. This suggests that a reasonably priced fringe lot would attract users who are sensitive to downtown parking costs.

Estimating Fringe Parking/Park-and-ride Demand Modeling

Hendricks and Outwater (1998) developed an approach to incorporate consumer park-and-ride lot decisions into the King County, Washington modeling process based on a method developed for the Puget Sound Regional Council (PSRC). The purpose of this project was to find a better way to predict future demand for 17 (out of a total 115) park-and-ride facilities that are candidates for capacity expansion. The significance of these efforts was that the attributes of individual park-and-ride facilities, such as capacity, fees and other amenities that can influence a user's decision to use a particular facility, can be included in the modeling process.

This study centered around the belief that a traveler's decision to use a park-and-ride facility is based largely on the time and cost associated with parking and utilizing transit for the remainder of his or her trip as well as the availability of space at the parking lot. The approach taken by Hendricks and Outwater (1998) incorporated a users' sensitivity to changes in characteristics of a particular facility by using a logit intermediate point choice model:

$$G_{pkq} = \frac{g_{pq} * e^{(U_{pk}^{au} + U_k + U_{kq}^{tr})}}{\sum_{k'} e^{(U_{pk'}^{au} + U_{k'} + U_{k'q}^{tr})}}$$

where

G_{pkq} = the number of trips from p to q using parking lot k, split by automobile portion and transit portion

g_{pq} = the combined matrix for the automobile park-and-ride access mode

U = the disutility functions expressed as linear equations of significant variables

First the auto disutility (as a function of time and cost), lot attractivity (as a function of cost and security) and transit disutility (as a function of time and cost) was calculated. These disutilities were used to derive the unconstrained park-and-ride demand. Then, in a feedback loop, the park-and-ride trips were distributed based on lot capacities and utilities; the auto, transit and lot disutilities were recalculated due to the capacity restraint; and the constrained demand was recalculated based on the revised disutilities. The park-and-ride trips were then redistributed and the loop continued until equilibrium is reached.

The model was validated using both user and non-user surveys that had been conducted by Market Data Research Corporation. The user survey included questions about the users' demographics and travel characteristics, factors contributing to their decision to use park-and-ride, assessment of existing conditions and feelings about how a user fee increase to improve conditions at their lot would affect their decision to use the lot. The non-user survey asked people who live near a park-and-ride lot why they do not use the lot and what could encourage them to begin using the lot.

The results of the model showed that when capacity constraints were added to the model as an attribute of the lot, for the 2010 forecasts, there was a 54% decrease in the number of park-and-ride trips. This result indicated that a traveler's decision to use a park-and-ride lot is strongly affected by the number of parking spaces available, which is confirmed by the non-user survey. The model results for the increased parking fee and the park-and-ride facility also corresponded with the user and non-user survey responses. Hendricks and Outwater (1998) concluded that including the attributes of park-and-ride facilities by making the facilities an additional user decision in the demand model provides planners and modelers with a more accurate estimation of the utilization of park-and-ride facilities.

One difference in modeling fringe parking and traditional park-and-ride is the factor on which users base their lot choice. In the case of park-and-ride, users are more likely to choose the lot closest to their origin (in the case of commute trips, home) whereas fringe parkers are more likely to choose the lot closest to their destination. The rationale behind this argument is that once fringe parking users have endured traffic congestion to get to the outskirts of the CBD, the travel distance between lots is less significant than the egress mode travel time (AECOM, 2003).

Mufti, Golfin and Dougherty (1977) designed a method to determine the optimal location for a fringe parking facility and the number of spaces to have at the facility. This study was completed in conjunction with a 1974 Delaware Valley Regional Planning Commission (DVRPC) study of 20 potential fringe parking sites at rail stations that had been identified by such characteristics as land availability, highway accessibility, rail ridership and parking demand.

There were four tasks involved in determining the parking demand at each of the potential lot locations. The first was to determine the potential market for each of the sites. This included the definition of the areas of possible trip origins and trip destinations and the tabulation of trips between these areas in the future. The origin area for parkers at a particular lot was defined as the area where the parkers reside. A maximum origin area for each of the lots was determined by the maximum time that a person would be willing to travel (based on the experience of the researchers). A "utilitarian mode-choice model" was used for the second task – to determine how many of the people in the area for each lot would be likely to use rail as a mode of transportation. The third task was to determine the number of rail passengers at each of the potential lot locations who would require parking at that lot. Mufti, Golfin, and Dougherty (1977) hypothesized that "there is a relationship between the distances patrons travel to the station and their access modes to the station." This means that patrons who live closer to the station would be more likely to use transit or kiss-and-ride, where patrons who live farther from the station would be more likely to use park-and-ride. The researchers plotted the percentage of passengers who park-and-ride at rail stations against the mean access distance to the station (based on the TAZ centroid location) to determine the number of people who would be likely to park-and-ride at a station. That number was then divided by the regional auto occupancy to determine the need for parking spaces. The fourth task took the space requirements from each of the lots and compared it to existing lot capacities to determine the need (if it existed) for more parking.

Mufti, Golfin and Dougherty (1977) found that the when they calculated park-and-ride user percentage ranges for mean access distances, the data showed the highest variation due to causes such as differences in automobile ownership, local feeder service and income level. Despite this, the researchers used the “medium” park-and-ride user numbers to determine the necessary supply of spaces at each lot because it was a more conservative estimate. The demand was calculated with an unconstrained supply.

Park-and-Ride and Fringe Parking Pricing

Carrese, Gori and Picano (1997) presented a procedure for a pricing simulation for park-and-ride planning. Their procedure considered the traveler’s decision-making process when parking availability and urban area accessibility are weighed against each other. This research was then applied to a changing parking situation in Rome when a new university was constructed on the outskirts of the city.

In their approach, parking costs were treated as part of the whole trip cost. Network equilibrium was based on road congestion and park-and-ride lot capacity. In a modeled situation where there is more parking supply than demand at the traveler’s destination, the lowest-cost lots that are closest to the destination became full before other lots are utilized. In cases where there are more travelers to a destination than there are parking spaces, some travelers shifted to either park-and-ride or transit, which could be modeled with a multi-modal assignment, or network congestion was affected by new lots being constructed, which could be modeled using a variable demand assignment model. In both cases where parking demand exceeds parking supply, road congestion played a major role in the modeling.

The park-and-ride mode was added to the existing auto and transit network by creating transfer links from the auto mode to the park-and-ride mode and from the park-and-ride mode to the transit mode. For a park-and-ride mode trips, the following components were considered:

- Access time to auto
- Travel time in auto
- Time required to park
- User out-of-pocket cost for the park-and-ride lot
- Transfer time
- Waiting time
- Transit travel time
- Time required to walk to final destination

The travel time in auto and transit and the time required to park were all congestion dependent and were results from the multi-modal assignment model. The authors used the parking plan for the area surrounding the University of Roma Tre as a test case for the model. The park-and-ride lots were located at subway stops. The model was able to separate two user classes (students and workers) to show a much higher sensitivity to time for workers, which was based on survey results. Using a scenario of unlimited destination and park-and-ride parking, Carrese, Gori and Picano (1997) examined three different destination parking cost scenarios. They found that since the travel time was weighed much higher than parking costs for the workers, a parking increase had a much smaller effect on mode split than the same increase had on students' mode split because students are much more sensitive to cost. The model could be used for the final analysis of a proposed destination parking facility (with space constraints) and parking costs.

Hensher and King (2001) studied the role of parking pricing on weekday non-commuter mode choice in Sydney, Australia. These trips included choice trips (shopping, social) and business-related trips. Hensher and King (2001) used a stated preference analysis to identify users' responses to changes in CBD parking cost and supply. Survey respondents were asked to state their mode of preference for their trips. The drive-and-park choices were drive and park in the CBD, park elsewhere in the CBD and park in the CBD fringe. The other choices were drive and park outside the CBD (with no fee), take transit and finally not traveling to the CBD. The survey was distributed to both current automobile and transit users to study mode shifts. The surveys posed different mode alternatives (which included cost, egress distance and hours of operation) and asked survey takers to evaluate the alternatives.

Hensher and King (2001) used a nested logit structure to estimate the stated preference data after evaluating different model structures. The nested logit model used attributes that were part of the stated preferences survey and other important attributes.

Hensher and King (2001) found that the parking price per hour was the most statistically significant attribute influencing parkers' decisions. They concluded that raising prices in the downtown core for short-term parking did not cause a loss of trips to the CBD and would most likely cause travelers to shift to transit usage or lead to travelers parking elsewhere in the CBD. This study reiterates that fringe parking is not suited to short-term parkers who are not as likely to tradeoff convenience for cost savings as long-term parkers are.

Modeling Fringe Parking

In a discussion with James Ryan, Chief, Office of Planning of the Federal Transit Administration, different aspects of modeling fringe parking in the regional model were discussed. Mr. Ryan stated that one of the most important reasons to have fringe parking trips within the regional model (as opposed to using an off-model analysis) is that fringe parking trips compete directly with other modes of transit, most notably park-and-ride. Without having fringe parking as a choice in the regional model, it is not possible to capture benefits from those trips in the forecast. From the perspective of FTA, cities studying transit options that would serve a fringe parking lot (either existing or planned) would need to include fringe parking as part of the regional model.

Mr. Ryan citied Pittsburgh as an example of a city where a study of a light rail transit extension would include service to a well-used fringe parking lot. However, modeling that lot (as well as the four other fringe lots around the CBD) as a park-and-ride lot did not capture the behavior of those lots as fringe parking. One of the reasons is that walking was generally a faster egress mode than transit for the fringe lots. The path builder in the model would not find trips to these lots coming from the entire region when the lots were modeled as park-and-ride lots. This led to the incorporation of fringe parking in the Southwestern Planning Commission (SPC) model, which includes Pittsburgh and its surrounding suburbs, in order to estimate fringe parking trips for this study. This model development will be discussed in detail later in this chapter (Ryan, 2004).

A quantitative way to measure benefits is to use the forecast from a regional model to calculate "user benefits." User benefits is "the aggregate difference in 'user costs' between a pair of alternatives, summed over all existing and new users of the transportation system" (FTA, April 2004). Using a software program called SUMMIT, which was developed by FTA, the user benefits calculation can be done and a time unit (in hours) of user benefits calculated for productions from each TAZ and attractions to each TAZ. The calculation of user benefits is required by FTA for the evaluation of Major Capital Investments in Transit (New Starts) project studies (FTA, April 2004). New Starts funding can be used for new fixed guideway or extensions to existing fixed guideway systems. User benefits is used to calculate user cost effectiveness as well as mobility improvements which are "normalized travel time savings" measured by transportation system user benefits per passenger mile on the New Starts project (FTA, April 2004). User benefits could also be used as a planning tool outside of a New Starts project submission. Examples of this would be the evaluation of the impact of proposed new transit service or possible transit service reductions compared to the existing service.

AECOM developed a fringe parking model that was incorporated into the HBW nest of the Southwestern Pennsylvania Commission (SPC) regional model, which is maintained in MINUTP (AECOM, 2003). This task was completed in response to FTA comments after the review of the Final Environment Impact Statement (FEIS) for the North Shore Connector study in Pittsburgh. Previously, the fringe parking market was estimated using a spreadsheet-based analysis; however, for project ridership due to fringe parking to be counted as ridership for the New Starts submittal process, the forecasts had to be run within the regional model.

The fringe parking model was calibrated using a 1995 survey of the fringe parking lots around the CBD: Three Rivers Stadium/North Side, Station Square, the Civic Arena, and the Strip District. Pittsburgh is a good example of a city that benefits from fringe parking. A 2002 study by the Allegheny Institute for Public Policy found that Pittsburgh has only 390 downtown and fringe parking spaces for every 1000 employees (Allegheny Institute, 2002). Incidentally, Pittsburgh is a good example of using multi-purpose lots for fringe parking. Two lots are adjacent to professional sports facilities (the Civic Arena and Three Rivers Stadium) and the other two are areas with restaurant, bars, clubs and other entertainment venues, which are predominantly evening and weekend destinations. The survey was conducted by SPC and Port Authority Transit (PAT) and consisted of a mail-in postcard distributed on a weekday morning at each of the lots. Parking patrons were asked their origin and destination, the purpose of their trip, the approximate time they entered the parking lot and their planned mode of egress to their final destination. A total of 2774 usable responses (out of approximately 6500 received) were geocoded to use for travel demand forecasting purposes (PAT and SPC, 1995). The analysis that was prepared from these survey results was used by AECOM is to determine the best way to model fringe parking riders.

It was found that the vast majority of these trips (98.4%) were home-based-work trips. Also, PAT collected vehicle occupancy information as cars entered the lots. Over ninety percent (92.1) of the cars entering the lot had only one occupant. The average vehicle occupancy was calculated to be 1.09 (PAT and SPC, 1995).

Based on the number of HBW trips, it was determined that the fringe parking mode would only be an option in the HBW model. Based on a GIS analysis, it was found that users of a particular lot were choosing that lot based not on their origin location, but on their destination location. As a result, the choice of a particular fringe parking lot was largely determined in the trip distribution part of the model, before mode choice. The main choice for users in mode choice is which egress mode to use (AECOM, 2003).

There are four possible egress modes in the fringe parking nest of the mode choice model: walk, shuttle, local bus, and LRT. Not all of the modes are available at all of the lots. The variables that contribute to the choice making include the in-vehicle time (the auto portion trip to the lot and the egress mode, if applicable) and the out-of-vehicle time (egress transit wait time or egress walking time). The out-of-vehicle time is weighted to be equivalent to 2.5 times the in-vehicle time. The cost for the fringe parking lot is expressed as an in-vehicle cost at 10 dollars/hour. There is also a transfer penalty for transferring between egress modes (AECOM, 2003).

In order to represent the maximum capacity at each of the fringe parking lots, an artificial price increase was included in the lot cost to prevent the lots from being overcapacity. This technique was used because the model does not have a place to input the number of available parking spaces in each zone. This cost was added iteratively during the fringe parking model calibration process to achieve the target values.

The artificial cost decreased the utility of fringe parking as a mode and reduced the probability of choosing that mode when compared to other modes.

Conclusions

Fringe parking is a parking management technique being used and tested both formally and informally in cities across the country. The differences in characteristics between fringe parking and park-and-ride parking are significant to warrant further research focusing on fringe parking as its own mode of transportation. The following chapter will detail a methodology for incorporating a fringe parking as a mode into a model based on the methodology developed by AECOM for Pittsburgh.

Chapter Three: Methodology

Introduction

The development of a fringe parking model within a regional model will allow for direct competition between fringe parking and other modes (auto, walk-to-transit, and park-and-ride). It will also permit the calculation of user benefits, which is a method to compare different alternatives to a common baseline. This could be important for cities studying transit options that would serve existing or planned fringe parking lots. Upon development, the model will be used to conduct sensitivity tests to examining users behavior to changes in fringe parking costs, egress level of service and the relationship between fringe parking and central business district (CBD) parking.

The research objectives are to (1) use the methodology developed in Pittsburgh to incorporate fringe parking into the mode choice model for another city and (2) to use that model to make observations about the behavior of fringe parkers. User benefits will not be calculated as part of this research; however, it would be possible to do so to evaluate the difference in transportation system benefits when different transit system variables are adjusted.

The Hampton Roads area model, which includes the City of Norfolk, Virginia, will be used as a test case.[1] The model was developed for Hampton Roads Transit (HRT) to meet FTA criteria to use for New Starts studies. Norfolk currently has three fringe parking lots with a projected parking deficit in the CBD core within the next ten years.

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[1] This work was completed as part of AECOM Consult's contract for the Hampton Roads Transit (HRT) 2004 Travel Demand Work Plan for the Norfolk LRT study.

The lots are within a mile of the CBD core and are well served by transit (including a proposed light rail line) making the city a good candidate for modeling fringe parking demand.

As part of this research, a fringe parking nest was incorporated into the existing mode choice model. This chapter will describe the methodology used for developing the model including determining existing conditions, data collection, control total calculation, and model calibration. Implications for future year forecasts including CBD core parking deficits will also be discussed. Sensitivity tests using the model will be discussed in the next chapter.

Case Study: Norfolk Virginia

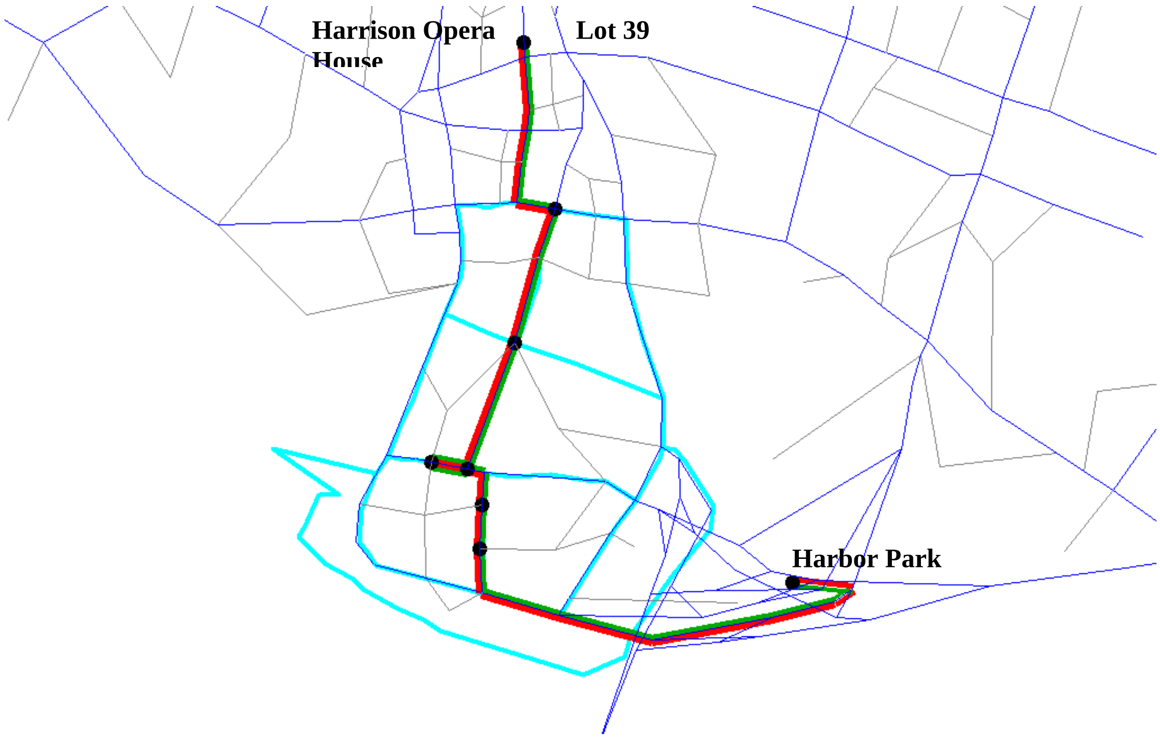
Norfolk, Virginia is the “cultural, educational, business, and medical center” of southeastern Virginia – a region that also includes the cities of Virginia Beach, Chesapeake, Portsmouth, Hampton and Newport News (City of Norfolk, 2004). Norfolk is bordered by Virginia Beach on the east, the Chesapeake Bay on the north and the Elizabeth River on the west and south. Norfolk is home to over 230,000 people and covers 66 square miles. Currently Norfolk is experiencing a downtown renewal with new business and retail openings, and restaurant and other entertainment construction. Currently, parking is readily available in the downtown area for all of these trip purposes; however, by the 2010, it is forecasted that there will be long-term (all-day) parking deficits in the downtown core if the downtown activity continues to grow and parking supply remains constant (Walker Parking Consultants, 2001).

The City of Norfolk Parking Division operates three fringe parking lots. These lots, Harbor Park, Harrison Opera House and Lot 39/Cedar Grove, are located on the edge of the CBD area. All three lots are surface lots that require monthly leases. Lot 39 is located at the corner of Virginia Beach Blvd. and Monticello Avenue. Bank of America employees who are provided with shuttle buses to the Bank of America building downtown use this lot. The Harrison Opera House lot is located at 160 Virginia Beach Blvd. The lot is used by city employees (including employees of the Department of Human Services) and individual leaseholders. At Harbor Park, lots are available to individual leaseholders as well as city employees. There is a shuttle bus provided for the School System Administration and a shuttle for Sheriff Department employees from Harbor Park.

People who park in Norfolk's three fringe parking lots have different options for their egress mode, the mode of transportation that they use to travel from the parking lot to their final destination. Walking is an option for those people whose final destination is close to the lot. Other motorized options exist at each of the lots. The NET is the Norfolk Electric Transit, a free downtown circulator operated by Hampton Roads Transit (HRT). At the south end of the route, the NET begins at Harbor Park (adjacent to the lots used by monthly lease holders) and travels north to the Harrison Opera House or Lot 39 (depending on the time of day) via St. Paul's Blvd, Main Street and Granby Street before returning southbound. In the peak period, the northern terminus is at Harrison Opera House and in the off-peak period, Lot 39. The NET stops are convenient to commercial and residential areas as well as tourist attractions.

Graphic 3-1 shows the three fringe parking lots with the existing NET service. The current NET service is shown in red and green (northbound and southbound). The TAZs in the CBD core are highlighted in cyan. The CBD core definition will be discussed later in this chapter.

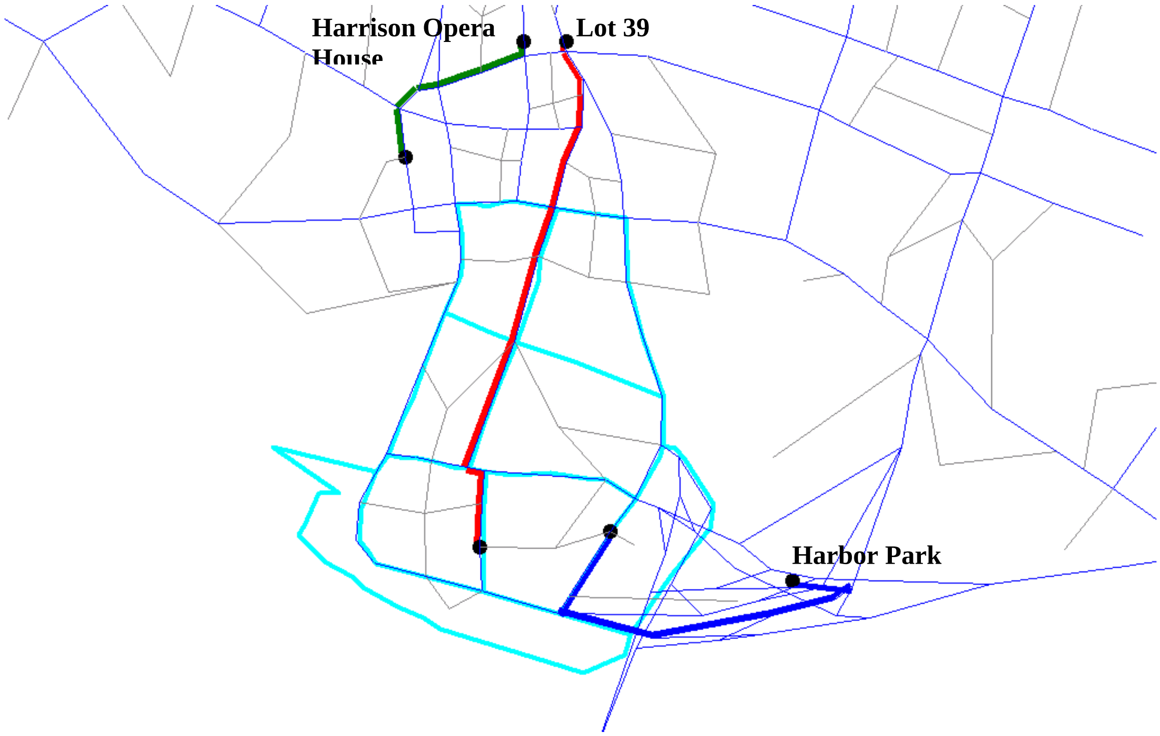
Graphic 3-1: Map NET Service



In addition to the NET, there is shuttle bus service available at each lot. A shuttle bus has no fare and is only available to persons for whom it is provided by their employer. The Division of Parking maintains a contract with a private bus company and administers a program on behalf of Bank of America and the Norfolk School System Administration. The Department of Human Services administers its own program as part of this contract. All of the shuttle buses make a direct trip from the lot to the destination.

At Lot 39, the shuttle bus for the Bank of America takes employees to the downtown location (at One Commercial Place). The full-size buses stop at the HRT stop, departing as they fill. During the morning peak period, there is a minimum of four buses in operation. At the Harrison Opera House lot, there is a shuttle bus provided for the Norfolk Department of Human Services employees (located at Duke St. and Brambleton Ave.). The bus circulates through the lot to pick up riders who are waiting in or near their vehicles. At Harbor Park, there is a shuttle bus provided for employees working at the School System Administration building (located at the intersection of St. Paul's Blvd. and City Hall Ave.). The morning bus service for the School System Administration runs only from 7 am until 8:30 am. The bus circulates through the lot similar to the shuttle bus at the Harrison Opera House lot. Graphic 3-2 shows the three shuttle routes. The School System Administration shuttle is in blue, the Bank of America shuttle in red and the Department of Human Services shuttle in green.

Graphic 3-2: Map of Shuttle Bus Service



The Hampton Roads Model

Using a methodology to what was used in Pittsburgh (AECOM, 2003), a fringe parking model was incorporated into the Hampton Roads regional mode choice model. The fringe parking nest was added to both the year 2000 model (for calibration purposes) and the year 2026 model (for forecasting purposes). The year 2026 model was used for analysis and sensivity tests because there is a forecasted parking deficit in the CBD core. This chapter will describe the existing 2026 Hampton Roads model, and the changes made to the mode choice step of the model in order to accommodate a fringe parking model. The Hampton Roads regional model is a traditional four-step model: trip generation, trip distribution, mode choice and trip assignment. The model is maintained in the TP+ modeling package. For this research, the change made to the existing

Hampton Roads model was in the mode choice part of the model where the fringe parking mode was integrated into the overall regional model and subject to the mode choice model decisions.

The fundamental unit of analysis for the travel demand forecasting methodology is the traffic analysis zone (TAZ) or simply, the zone. Both the trip tables and the highway and transit networks define transportation supply and demand as trips and travel time (or cost) at the zonal interchange level (i.e. from production zone to attraction zone).

The current Hampton Roads model area system is comprised of 1480 TAZs:. The zone system includes the jurisdictions on the Southside (Norfolk, Virginia Beach, Portsmouth, Chesapeake, Suffolk, and Isle of Wright) and the Peninsula (Newport News, Hampton, Williamsburg, Poquoson, York County, James City County, Gloucester City and County). Internal zones 1-999 are “Southside” areas and 1000-1447 are on the Northside or “Peninsula.”

The model contains socioeconomic productions for the years 2000 and 2026 that have been produced by the region’s MPO Hampton Roads Planning District Commission (HRPDC). These attributes, which include household population, auto ownership, dwelling units, retail employment, and non-retail employment, are used for generating the trip tables for the model.

The Mode Choice Model

The mode choice model is designed to take person trip tables from trip distribution, travel characteristics for both highway and transit services, socio-economic variables and other characteristics at the traffic zone level, and various coefficients and parameters and subdivide the person trip tables by travel mode.

The Hampton Roads mode choice model is a multinomial logit model form, which is a commonly used operational mode choice model in the United States:

$$P_{g,i} = \frac{e^{[U_{g,i}(x_{g,i})]}}{\sum_m e^{[U_{g,m}(x_{g,m})]}}$$

where:

$P_{g,i}$ is the probability of a traveler from group *g* choosing mode *i*;
$x_{g,i}$ are the attributes of mode *i* that describe its attractiveness to group *g*; and
$U_{g,m}(x_{g,m})$ is the utility (or attractiveness) of mode *m* for travelers in group *g*.
(Source: AECOM, 2004)

The utilities are summed over all available modes. The utility equation usually takes the form:

$$U_{g,m}(x_{g,m}) = a_m + b_m\, LOS_m + c_{g,m}\, SE_g + d_m\, TRIP$$

where:

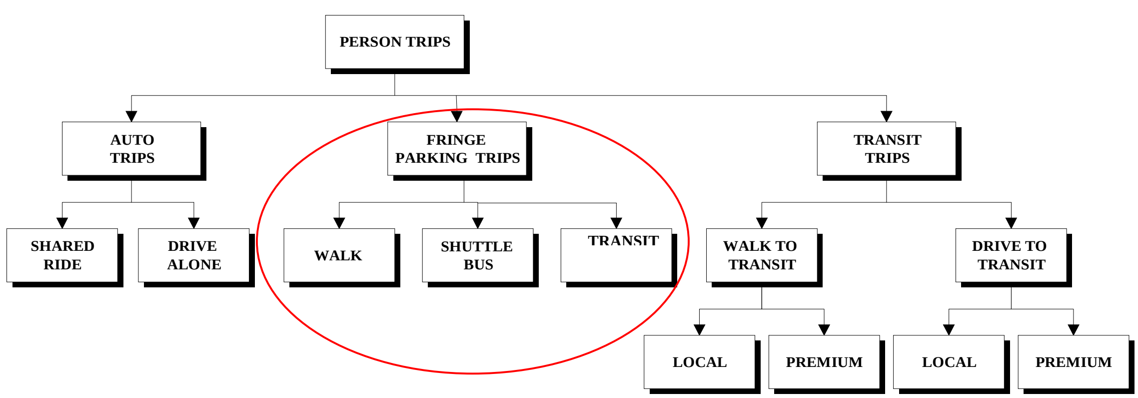
LOS_m is a variable set describing levels-of-service by mode *m*;
SE_g is a variable set describing the socioeconomic characteristics of group *g*;
TRIP is a variable set describing the characteristics of the trip;
b_m is vector of coefficients describing the importance of each LOS_m variable;
$c_{g,m}$ is vector of coefficients describing the importance of each SE_g characteristic of group g with respect to mode *m*
d_m is vector of coefficients describing the importance of each TRIP characteristic of with respect to mode *m*, and
a_m is a constant specific to mode *m*.
(Source: AECOM, 2004)

The mode choice model produces estimates of person trips by mode as well as auto vehicle trips by occupancy category and thus combines the mode split and auto occupancy process. As implemented, the mode choice model operates for three trip purposes on the post-distribution person trip tables: home based work (HBW), home based other (HBO), and non-home based (NHB). Peak travel times are used for home-based work and off-peak times for the non-work purposes. This approach allows for sensitivity to highway congestion since transit times for work “compete” with congested highway times in the mode choice model.

The Fringe Parking Model

Fringe parking is only incorporated into the Home-based Work (HBW) mode choice model. This is done because commuter (work) trips are the primary market for fringe parking trips and all work trips are modeled in the AM peak period. Additionally, fringe parking is only allowable for households with one or more car. Graphic 3-3 shows the full nesting structure for the HBW purpose. The red circle indicates the fringe parking nest that was incorporated as part of this research.

Graphic 3-3: Mode Choice Set



(Source: AECOM, 2004)

Data Collection

To determine targets for model calibration, data were collected from each of the three lots. The data will be expanded to match leaseholder information provided by the City of Norfolk.

In order to capture the jurisdiction of origin and mode of egress on an average weekday, three consecutive Wednesdays (April 14, 21, and 28, 2004) were chosen. Cruise ship passenger activity and Norfolk Tides games affect the parking availability at Lot 39 and Harbor Park respectively. On days when a large cruise ship is out of port, people who normally park at Lot 39 are relocated by the Division of Parking to Harbor Park to allow cruise ship passengers to park at Lot 39. This meant that data collection had to be completed when there was not a large cruise ship out of port (passenger parking for a small cruise ship does not affect monthly lease holders at Lot 39). A time window between April 2 and June 6, 2004 was available. At the request of the Division of Parking, the data collection could not be conducted on a day where any cruise ship was departing because there would be too much activity at Lot 39. Furthermore, data could not be collected on a date of a home daytime game for the Norfolk Tides because monthly lease parking would be restricted at the Harbor Park lots.

Data were collected for egress mode and origin location for those persons and vehicles parking at the three fringe parking lots (origin-to-destination format). The data collection was completed between 6 am and 9 am (the morning peak period) on each of those days. The number of data collectors at each lot was determined based on the sightlines at each lot and were adjusted in subsequent weeks as needed. The weather was similar all three weeks – moderate temperature (high 50s/low 60s early, warming to the low-to-mid-70s) and no significant precipitation.

There were three pieces of data collected: the egress mode of each person leaving the lot, the origin (based on county or city sticker which indicates the jurisdiction where the local vehicle registration fee was paid) of each vehicle in the lot and the number of shuttle buses that served each lot during the data collection time period (in order to determine average headway).

The available egress modes were the same for each lot: NET, walk, or shuttle bus. The data collection sheets broke the three-hour time period into 15-minute increments. The data collectors counted each person as he or she left the lot. Only those people who got out of cars parked in the lot were counted. Anyone who walked away from the lot was counted as a walker. Anyone who walked to the NET stop was counted as a NET rider. Anyone who boarded a shuttle bus was counted as a shuttle bus rider. The cruise ship parking at Lot 39 was not counted

At 9 am, the county or city sticker on each of the vehicles was tallied. This count would include vehicles that parked in the lot before 6 am. The county or city sticker information was collected to determine the approximate regional split of origins of those persons parking in the lot. Virginia Beach is the only locality in the Hampton Roads area that does not issue a city sticker. If a vehicle had Virginia license plates and no county or city sticker, it was assumed to be from Virginia Beach. Any vehicle with a county or city sticker for a Virginia jurisdiction outside of the metropolitan area or an out-of-state license plate was counted under “other.”

Data Summary

The data for each lot was summed over the three weeks. This was done to reduce any potential for oddities on one of the data collection days. The data in Table 3-1 is in origin-to-destination format and the mode share percentages have been calculated.

Table 3-1: Mode Share Calculations (Three Week Totals)

Harbor Park		**NET**	**Walk**	**Shuttle Bus**	**Total**
	Data (3 weeks) **Mode Share**	608 44%	621 45%	164 12%	1393 100%
HOH					
	Data (3 weeks) **Mode Share**	9 2%	360 68%	157 30%	526 100%
Lot 39					
	Data (3 weeks) **Mode Share**	0 0%	15 1%	1404 99%	1419 100%
All Lots					
	Data (3 weeks) **Mode Share**	617 18%	996 30%	1725 52%	3338 100%

Table 3-2 shows the origin jurisdiction data that were collected and summed over three weeks, by lot, and the calculated percentages of vehicle origin. Each of the three lots had a consistent split between jurisdictions during the three weeks. Furthermore, each of the three lots shows a similar breakdown of vehicle origins. The largest populations are from Virginia Beach and Norfolk, followed by Chesapeake and Portsmouth. These data are used to verify the trip table in the model.

Table 3-2: Origin Jurisdiction Calculations

	Harbor Park		**Harrison Opera House**		**Lot 39**	
Origin Jurisdiction	**Data**	**% of Total**	**Data**	**% of Total**	**Data**	**% of Total**
Norfolk	342	23%	133	24%	400	25%
Virginia Beach	582	39%	191	34%	567	36%
Portsmouth	75	5%	40	7%	119	8%
Chesapeake	248	16%	115	21%	217	14%
Suffolk	77	5%	14	3%	63	4%
Newport News	15	1%	11	2%	45	3%
Hampton	21	1%	9	2%	78	5%
Poquoson	0	0%	0	0%	0	0%
Franklin	1	0%	0	0%	0	0%
Williamsburg	0	0%	0	0%	0	0%
Gloucester County	1	0%	0	0%	1	0%
Isle of Wight County	4	0%	0	0%	0	0%
James City County	1	0%	2	0%	3	0%
Southampton County	0	0%	0	0%	0	0%
Surry County	0	0%	0	0%	0	0%
York County	2	0%	3	1%	1	0%
Other	136	9%	40	7%	87	6%
TOTAL	1505	100%	558	100%	1581	100%

The number of shuttle buses that departed from the lots during the data collection period was counted in order to calculate the average headway for each bus route over a three-hour period. The headway is the average length of time between buses, which is three hours (180 minutes) divided by the number of buses observed during that time period. At Lot 39 and the Harrison Opera House, the shuttle buses do run during the entire three-hour period. At Harbor Park, however, the shuttle bus only runs for half of the time (from 7 am – 8:30 am). Since the peak period in the model is three hours, the headway needed to be calculated over a three-hour period for all of the buses. Table 3 shows the average headway calculated for each of the three shuttle buses.

Table 3-3: Shuttle Bus Headways

Lot	Shuttle Bus Destination	# Buses	Headway (6-9am)
Harbor Park	School System Administration	8	22.5 min
Harrison Opera House	Dept. of Human Services	20	9 min
Lot 39	Bank of America	32	5.6 min

Control Totals

In order to determine the mode share percentages for each lot, the three weeks of data were added together. The mode share was calculated over all three lots to obtain a mode share for fringe parking. Table 3-1 shows this calculation. The origin jurisdiction totals in Table 3-2 will be used for a reasonableness check on the model trip table.

The Division of Parking has records for the number of monthly lease holders at each lot and assumes 85% as its effective capacity for the entire system. The effective (average) daily number of parkers for each of the fringe parking lots is shown in Table 3-4. In order to determine the control totals for the model calibration, the effective number of monthly leaseholders (average number of daily parkers) had to be multiplied by two to represent the two trips involved in each work trip (to change the origin-destination data collected in the survey to production-attraction format required for the model). Since the monthly parker information obtained from the city is based on the number of vehicles (permits issued), the effective capacity was then multiplied by an auto occupancy factor

(1.1) to obtain the number of people parking in each lot. The mode totals for each lot and for all lots were expanded to this number. Table 3-5 shows the control totals by lot and for all lots (P-A format).

Table 3-4: Average Daily Parkers

Lot	Average Daily Parkers
Harbor Park	883
Harrison Opera House	501
Lot 39	838

Table 3-5: Fringe Parking Mode Share Control Total Calculation

	NET	Walk	Shuttle Bus	Total
Harbor Park	848	866	229	1,943
HOH	19	754	329	1,101
Lot 39	0	19	1,824	1,844
All Lots	904	1,459	2,526	4,888

The Fringe Parking Network

The fringe parking networks for were created based on the fringe parking lot data collection. The maximum drive access time for fringe parking is 40 minutes. For productions zones within that requirement, fringe parking impedances are calculated for the three fringe parking modes: fringe parking with walk egress, fringe parking with transit egress and fringe parking with shuttle bus egress. Table 3-6 shows the fringe parking path-building parameters.

Table 3-6: Fringe Parking Lot Path Building Parameters

Parameter	Fringe Parking/Walk Egress	Fringe Parking/Transit Egress	Fringe Parking/Shuttle Bus Egress
Access/Egress Modes	Lot access Shuttle bus boarding/alighting	Lot access NET boarding/alighting	Lot access Walk egress
Line Haul Modes	Drive to fringe lot Shuttle bus	Drive to fringe lot NET	Drive to fringe lot
Initial Wait	½ headway (if headway < 15 min) 7.5 + 0.25(headway-15) (if headway > 15 min)	½ headway (if headway < 15 min) 7.5 + 0.25(headway-15) (if headway > 15 min)	½ headway (if headway < 15 min) 7.5 + 0.25(headway-15) (if headway > 15 min)

Table 3-7 and 3-8 show the new mode choice model coefficients and constants for each of the purposes. Key independent variables in the models are in-vehicle time (IVT), out-of-vehicle time (OVT), and travel cost. The drive access to transit and fringe parking submodes are present for home-based work trips (HBW) but not for the HBO and NHB purposes. The HBW drive to premium includes a small bias of 3.6 minutes.

Table 3-7: Mode Choice Coefficients

	HBW		**HBO**	**NHB**
	0 Car HH	*1+ Car HH*		
Variables				
In-Vehicle Time	-0.0250	-0.0250	-0.0250	-0.0250
Out-of-Vehicle Time	-0.0625	-0.0625	-0.0625	-0.0625
Cost	-0.0015	-0.0015	-0.0015	-0.0015
Transfer Penalty	-0.0075	-0.0075	-0.0075	-0.0075
Nesting Coefficients				
Auto-Fringe-Transit Nest	0.5000	0.5000	0.5000	0.5000
Walk-Drive-Transit Nest	0.3000	0.3000		

Top Level Nest Coefficients

Source: AECOM, 2004

The mode choice coefficients are specified by guidelines set by FTA (AECOM, 2004). The utilities are all represented as a time. For the attributes, out-of-vehicle time is weighted at two and a half times that of in-vehicle time, which means is it is two and a half times more cumbersome as IVT. In the Hampton Roads model, in-vehicle time refers to the time spent in an auto or transit vehicle (including drive-to-transit) and OVT is any portion of the trip on in a vehicle including walking to a transit stop, waiting for a transit vehicle, waiting to transfer to a second vehicle (if applicable) and walking to the final destination. There is a transfer penalty of three minutes (represented by three times in the IVT), which is applied to each transfer in addition to the OVT.

This research was intended to incorporate fringe parking into an existing model. The Hampton Roads model is used for studying proposed FTA-funded transit projects and because of this, the coefficients in the model are specified based on FTA guidelines. These guidelines were established based on experiences of many different cities and were put into place so that transit studies in different cities using their respective models would be directly comparable. In order to truly capture the mode choice decisions of travelers in the Hampton Roads area, data should be collected to more appropriately estimate the mode choice coefficients. Furthermore, the addition of a new mode into the mode choice model may call for reexamining the coefficients.

Table 3-8 Mode Choice Constants

	HBW 0 Car HH	HBW 1+ Car HH	HBO	NHB
Drive Alone		0.00000	0.00000	0.00000
Shared Ride	-1.12403	-1.12403	-0.18093	-0.09949
Walk to Local	-0.68968	-0.68968	-2.49088	-2.57229
Walk to Premium	-0.68968	-0.68968	-2.49088	-2.57229
Drive to Local		-1.76859		
Drive to Premium		-1.67730		
Fringe Walk		-1.42109		
Fringe Transit		-2.17104		
Fringe Shuttle Bus		-0.36241		

The mode choice constants came out of the mode choice calibration. Every mode is compared to "drive alone," where the constant was held constant at zero during the calibration. In the fringe parking nest, shuttle bus egress is the most desirable choice followed by walk and transit.

Fringe Parking Assignment

The trip tables produced by the mode choice model are assigned to the fringe parking paths:

- Fringe parking to shuttle bus egress
- Fringe parking to transit egress
- Fringe parking to walk egress

For each of the peak period, the appropriate trips are loaded on the above paths using an all-or-nothing procedure. It should be noted once again that this assignment is produced in production-attraction format, which is standard for transit analyses, rather than the origin-destination format more commonly used in highway assignments.

The following section discusses the data collection process and the calibration of the mode choice model which lead to the aforedescribed coefficients and constants.

Model Calibration

The HBW mode choice model with fringe parking was calibrated using AECOM's calibration software. While the HBO and NHB mode choice models were not part of this fringe parking study, the existing model calibration results are included for completeness. The calibration was also calibrated using AECOM's calibration software. Table 3-9 shows the model calibration results (in production-to-attraction format) for the egress mode by lot. Table 3-10 shows the model calibration results (in production-to-attraction format) for the shuttle bus boardings by route. The overall mode split calibrated well. On the route level, the model did not calibrate to the control totals as well. This could be because the number of trips is so small compared to the total number of trips in the region and the model and/or the trip tables may not be sensitive enough to calibrate the individual routes.

Table 3-9: Model Calibration Results: Boardings by Egress Mode

Mode	Observed	Modeled
NET	904	896
Walk	1,459	1,452
Shuttle Bus	2,526	2,513
Total	4,889	4,861

Table 3-10: Model Calibration Results: Shuttle Bus Boardings by Route

Route	Observed	Modeled
School System Administration	229	641
Department of Human Services	329	135
Bank of America	1,824	1,737

Table 3-11 shows the comparison between the observed control totals and the modeled origin jurisdiction (in origin-to-destination format). This comparison was not used in the calibration, but as a reasonableness check to ensure the modeled trips are close to the observed data.

Table 3-11: Model Calibration Results: Origin Jurisdiction

Origin Jurisdiction	Observed	% of Total	Modeled	% of Total
Norfolk	585	27%	533	22%
Virginia Beach	895	42%	1,002	41%
Portsmouth	157	7%	250	10%
Suffolk	100	5%	68	3%
Chesapeake	400	19%	573	24%
Isle of Wight County	3	0%	6	0%
Hampton	47	0%	0	0%
Newport News	68	0%	0	0%
Other	192	0%	0	0%
TOTAL	2,444	100%	2,431	100%

Table 3-12 shows observed versus modeled linked trips for each purpose. The HBO and NHB models were not calibrated as part of this research, but the calibration results are included for completeness (AECOM, 2004).

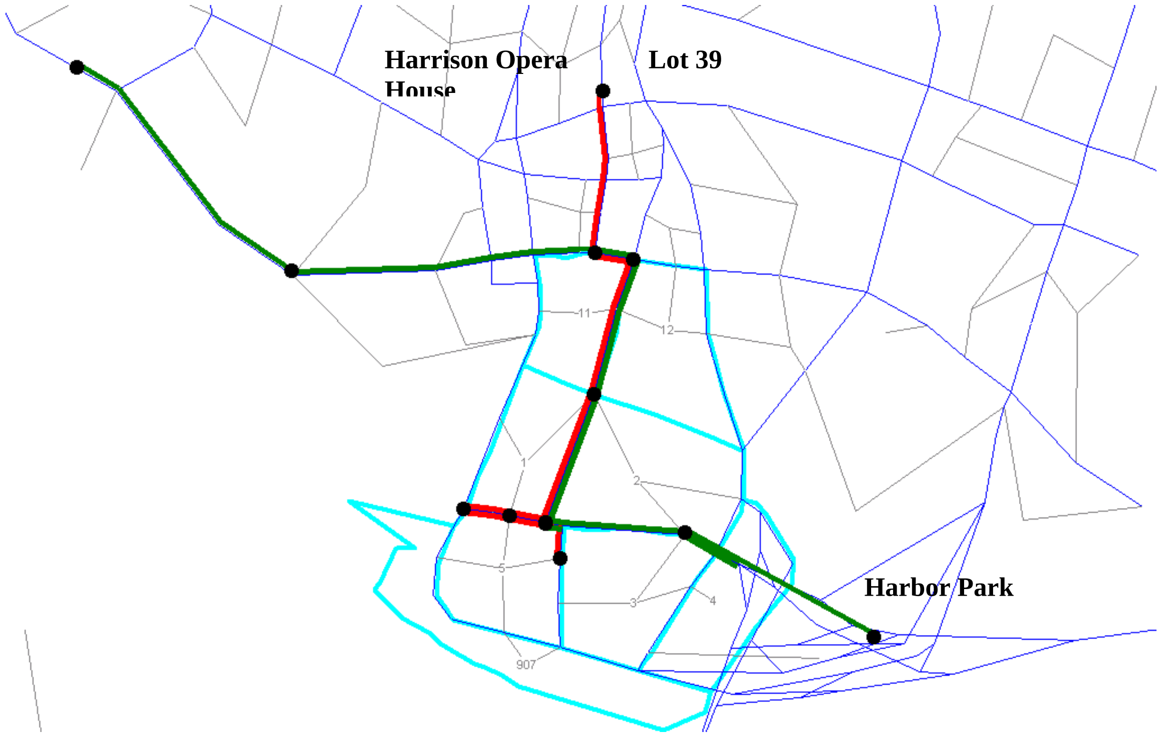
Table 3-12: Mode Choice Model Calibration

	HBW			HBO			NHB		
	Observed	*Modeled*	*% diff*	*Observed*	*Modeled*	*% diff*	*Observed*	*Modeled*	*% diff*
Drive Alone	845,536	841,560	-0.5%	1,932,828	1,932,868	0.0%	951,129	951,091	0.0%
Shared Ride	130,875	130,269	-0.5%	1,346,013	1,346,035	0.0%	779,529	779,497	0.0%
Walk to Local Transit	16,235	15,987	-1.5%	9,255	9,255	0.0%	4,627	4,627	0.0%
Walk to Premium Transit									
Drive to Local Transit	122	121	-0.8%						
Drive to Premium Transit									
Fringe Parking/ Walk Egress	1,459	1,451	-0.5%						
Fringe Parking/ Transit Egress	904	899	-0.6%						
Fringe Parking/ Shuttle Egress	2,526	2,516	-0.4%						

Future Year Forecasts

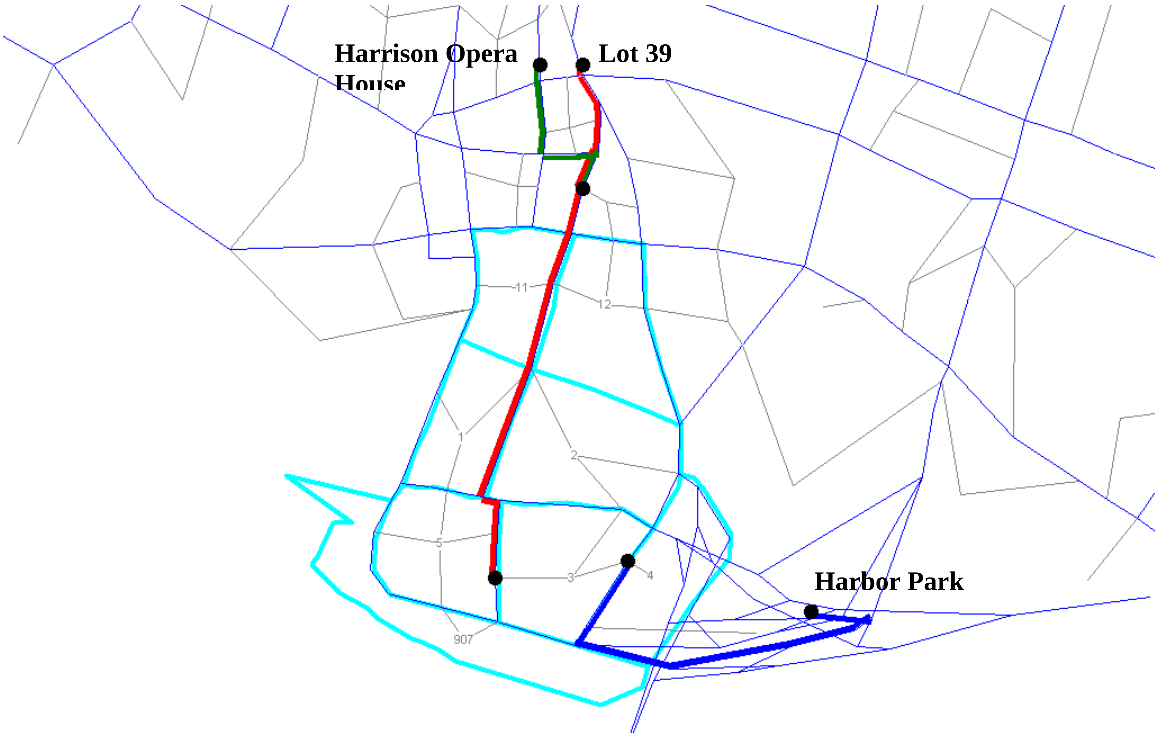
The 2026 model will be used for sensitivity tests because there is a forecasted parking deficit in the CBD core for that year. To study fringe parking usage in the future, additional NET service has been added to strengthen the fringe parking program. The additional NET service is an east-west route which begins at Harbor Park and travels through CBD core and ends at Eastern Virginia Medical Center (EVMC). Also, the Department of Human Services route from the Harrison Opera House lot has a different routing due to planned relocation. Graphics 3-4 and 3-5 show the future year NET and shuttle service.

Graphic 3-4: Future NET service



The red route is the future north-south NET and the green route is the east-west NET.

Graphic 3-5: Future Shuttle Bus Service



The red route is the Bank of America shuttle, the blue route is the School System Administration shuttle and the green route is the Department of Human Services shuttle.

Calculation of Future CBD Parking Deficits

For the sensitivity tests, two possible CBD core parking scenarios will be examined. The first is the situation where there is ample downtown parking. The second is where the downtown parking is limited by the actual projected parking for 2025/2026. The parking constraints will be incorporated to the model as an artificial price increase on the daily out-of-pocket parking cost.

In May 2001, the City of Norfolk contracted Walker Parking Consultants to complete a comprehensive parking analysis. One of the goals of the analysis was to determine the most effective way to utilize existing parking to avoid construction of new parking facilities. The analysis showed a parking shortfall in the “core” of the Norfolk

CBD. The Norfolk CBD core is defined as the area bordered by Boush Street, Brambleton Avenue, St. Paul’s Boulevard. (including Government Center), and Waterside Drive (including the parking at Waterside). The shuttle bus and NET service to the three fringe lots (Harbor Park, Lot 39, and the Harrison Opera House) effectively hide additional long-term (all-day) parking deficits. Graphic 3-6 shows a map with the zones in the CBD core highlighted in red.

Graphic 3-6: Zone Map of CBD Core

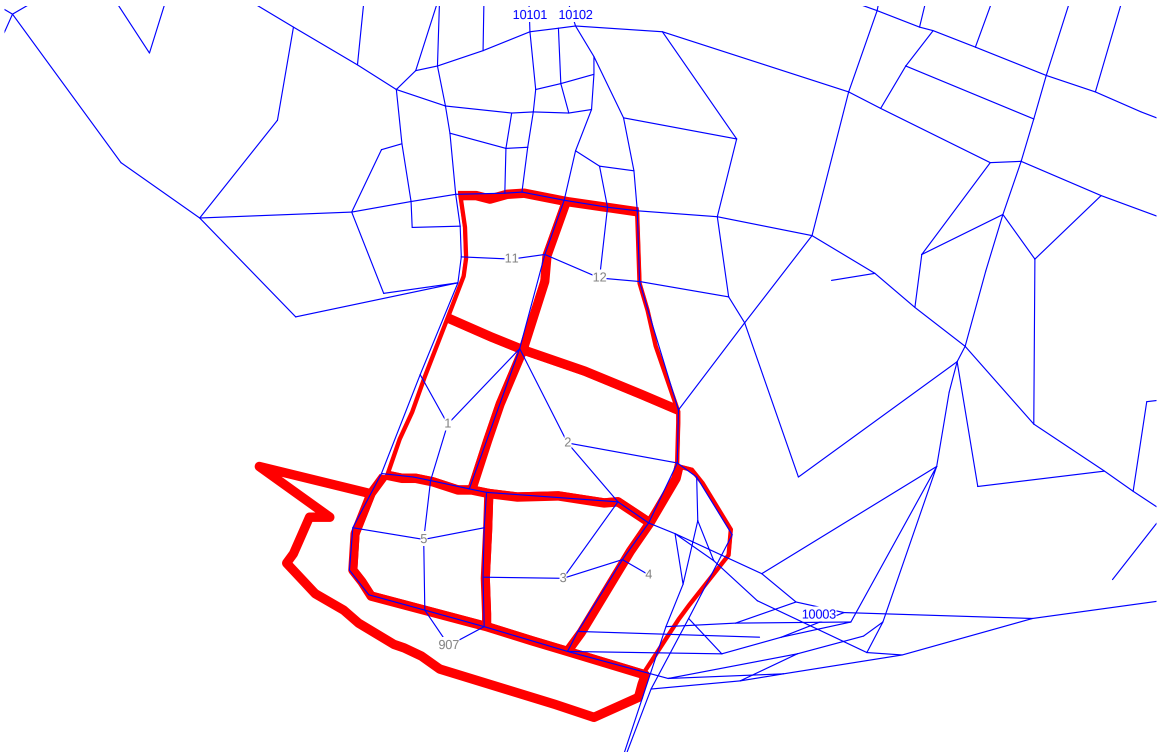


Table 3-13 shows the adjusted effective long term parking for the Norfolk CBD core. Dividing the 7,808 available spaces in 2010 by the 7,230 available spaces in 2000 yields a growth factor of 1.08.

Table 3-13: Norfolk CBD Core Long Term Parking

	2000	2010
Adjusted effective parking (Walker Parking Consultants, 2001) (1)	9,948	10,526
Less effective fringe parking included in adjusted total	2,718	2,718
Actual effective parking in core	7,230	7,808 (2)

1 85% of surveyed parking in CBD core and fringe parking facilities
2 Estimated for this research

Walker Parking Consultants only projected demand to 2010. However data from HRDPC indicated employment leveling off in the Norfolk CBD core after 2011 (Table 3-14). Thus the long term parking demand for 2025/2026 can be assumed to be equivalent to that of 2010/2011.

Table 3-14: HRPDC Employment Estimates

TAZ	2000	2011	2025
1	1,845	4,592	4,000
2	1,878	1,709	2,000
3	6,379	4,854	6,400
4	2,280	6,462	2,400
5	4,714	3,479	4,900
11	356	2,200	2,100
12	86	1,619	1,600
907	2,603	3,834	3,750
Total	20,141	28,749	27,150

Source: HRPDC

The “target” number of spaces required in 2025 can be estimated in the following manner

1. In 2000, there are 20,981 HBW trip attractions in the Norfolk CBD core
2. Subtracting out 5,087 fringe parking and transit trips yields 15,894 auto person trips (13,739 drive alone and 2,155 shared ride) auto person trips
3. This is 14,723 vehicle trips (using 2.19 occupancy factor for shared ride)
4. Dividing by 2 yields 7,361 spaces needed in 2000
5. Using the 1.08 growth factor from Table 3-13 yields 7,950 spaces in 2025

Zonal parking charges in TAZs 1, 2, 3, 4, 5, 11, 12, and 907 can be adjusted to achieve a demand for 7,950 spaces in 2025 for each alternatives simulated. For each zone, the average weekday parking cost was increased by the same amount, using an artificial price increase until the number of trips to the zones in the CBD core does not exceed the supply. The existing 2026 and inflated parking costs for the CBD core TAZs are listed in Table 3-15.

Table 3-15: Existing and Constrained CBD Core Parking Costs

Zone	Unconstrained CBD core average weekday parking cost *	Constrained CBD core average weekday parking cost **
1	$ 5.12	$ 17.60
2	$ 6.46	$ 18.94
3	$ 4.19	$ 16.68
4	$ 7.12	$ 18.60
5	$ 5.21	$ 17.69
11	$ 3.56	$ 16.04
12	$ 4.81	$ 17.29
907	$ -	$ 12.48
	* from HRPDC	* artificially inflated pricing

Application of the Fringe Parking Model

With the incorporation of fringe parking as a mode in the Hampton Roads mode choice model, fringe parking as a mode directly competes with auto and transit modes. This gives modelers the ability to study fringe parking and the effects of transportation system variable changes on fringe parking and fringe parking variable changes on the rest of the transportation system. This tool can be used to study parking pricing strategies for both fringe lots and the CBD zones and fringe parking egress mode service level options. The next chapter will show how this model can be applied and test the sensitivities of the model.

Chapter Four: Analysis

Introduction

The fringe parking model for Norfolk and its surrounding areas can be used as a tool for city planners to study fringe parking demand, the effects of fringe parking on CBD parking demand, parking pricing strategies and transit planning for fringe parking transit egress. In order to examine some of these relations, several sensitivity tests were conducted. The 2026 forecast year model was used for these sensitivity tests because of the forecasted parking deficit in the CBD core.

Base Case Scenario

There are three variables in the Norfolk fringe parking model that are feasible to change from the perspective of a city planner:

1. The CBD core parking daily parking lot cost
2. The daily fringe parking lot cost
3. The transit egress (NET) headway.

It is these three variables that will be studied at as part of the base case and the other sensitivity tests.

The CBD core parking cost is set at $6.50 per day in the model. This value is based on the Walker Parking Consultant recommendations for future parking pricing. The $6.50 cost in the Walker parking study applied to monthly parking rates in a narrower definition of the downtown core; however for this research that cost will apply to the CBD core definition as described in Chapter 3 (Zones 1-5, 11, 12, and 907). The parking costs for attraction zones are part of the COST attribute for the drive alone and shared ride modes. The fringe parking lot cost is set at $3.00 per day for each of the fringe parking lots. This value is partly based on Walker Parking Consultants' recommendations for future fringe parking lot costs. The fringe parking lot cost is part of the COST attribute for all fringe parking modes.

The transit egress headway was set at 10 minutes (or 6 vehicles per hour) for the north-south and east-west service NET. This headway is longer than the 2004 headway of 6 minutes for the north-south NET service. This is not an indication of future plans in Norfolk to reduce service. The 10-minute transit egress headway was chosen because it is within the range of successful headways found in the literature and a feasible level of service for many cities or transit agencies to provide.

To study some of the relationships in the model, all HBW trips from the region to Zone 4 were studied. Zone four was selected because it is adjacent to Harbor Park and can be accessed by all fringe parking egress modes.

Utility

Utility theory states that an individual has a finite set of choices and makes his or her decision based on the choice that maximizes his or her utility. This statement assumes that the individual "possesses perfect information" and makes rational decisions (NCHRP, 2001). Utility is derived from the characteristics of a choice. In a transportation model, a traveler can have a number of modes to choose from with characteristics or attributes can include in-vehicle travel time, wait time, cost, etc.

In the Hampton Roads model, utility is based on time. The coefficients represent all costs as a time and the alternative with the highest utility has the lowest overall time cost to in individual. A sample of a generic utility equation was shown in Chapter 3.

Table 4-1 contains the utility equations for the mode choice model (by nest) for the home-based work purpose. As shown in the previous chapter, the four attributes for modes in the model are in-vehicle-time (IVT), out-of-vehicle-time (OVT), out-of-pocket cost (COST) and the number of transfers (XFER). The equations in Table 4-1 pertain to households with one or more vehicle. For households with no vehicles, an additional constant of –9.9999 is added to the utility equations for modes that include an auto segment so that mode is not an option for those individuals.

Table 4-1: Utility Equations by Nest

AUTO

$U_{(DA)}$ = [-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.5
$U_{(SR)}$ = -1.12403 + ([-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.5

TRANSIT

$U_{(WLOC)}$ = -0.68968 +[-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.15
$U_{(WPRM)}$ = -0.68968 +[-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.15
$U_{(DRLOC)}$ = -1.76859 +[-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.15
$U_{(DRPRM)}$ = -1.67730 +[-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.15

FRINGE PARK

$U_{(FPWALK)}$ = -1.42109 +[-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.5
$U_{(FPTRAN)}$ = -2.17104 +[-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.5
$U_{(FPSHUT)}$ = -0.36241 +[-0.0250(IVT) – 0.0625(OVT) – 0.0015(COST) – 0.0075(XFER)]/0.5

where:
IVT - In-vehicle time (minutes)
OVT – Out-of-vehicle time (minutes)
COST – Applicable costs depending on mode: parking, transit fare, value of time (dollars)
XFER – Transfer Penalty (#of transfers)

Table 4-2 details the variables that comprise the attributes in the utility equations for the three modes in the fringe parking nest.

Table 4-2: Fringe Parking Variables

Fringe Parking Mode	IVT	OVT	COST	XFER
Fringe Park/ Transit Egress	Drive access time NET travel time	Production zone auto access Fringe lot access NET wait time Walk to attraction zone	Auto operating cost ($0.105/mile) Fringe lot parking cost	n/a
Fringe Park/ Walk Egress	Drive Access Time	Production zone auto access Fringe lot access Walk to attraction zone	Auto Operating Cost ($0.105/mile) Fringe Lot Parking Cost	n/a
Fringe Park/ Shuttle Egress	Drive Access Time Shuttle Travel Time	Production zone auto access Fringe lot access Shuttle wait time Access to attraction zone	Auto Operating Cost ($0.105/mile) Fringe Lot Parking Cost	n/a

Table 4-3 shows the average attributes values for person-trips between all zones and zone 4 as calculated from the output of the mode choice model.

Table 4-3: Average Attribute Values for Trips from All Zones to Zone 4

Mode	IVT		OVT		COST		XFER	
	value (minutes)	std. dev.	value (minutes)	std. dev.	value (dollars)	std. dev.	value (#)	std. dev.
Drive Alone	22.87	13.35	9.18	0.72	4.46	0.78	0.00	0.00
Shared Ride	20.50	11.58	9.18	0.72	4.53	0.88	0.00	0.00
Walk to Local	44.37	29.24	29.97	14.54	1.50	0.03	0.67	0.69
Walk to Premium	49.20	17.36	37.74	12.09	1.50	0.00	1.29	0.57
Drive to Premium	18.33	0.48	25.83	4.79	2.24	0.45	0.00	0.00
Fringe Park/Walk Egress	21.32	8.33	13.80	0.00	2.76	0.62	0.00	0.00
Fringe Park/Transit Egress	26.49	8.37	11.01	0.20	2.76	0.62	0.00	0.00
Fringe Park/Shuttle Egress	14.26	5.01	11.58	0.00	2.19	0.50	0.00	0.00

The average attribute values take into consideration the attribute values from indivdual production zones to attraction zones with paths for each available mode. For example, drive alone and shared ride paths were valid between 567 different zones and zone 4. The path build found 434, 435, and 238 zones with valid fringe parking and walk, transit and shuttle egress modes, respectively. These numbers are reasonable because the auto nest modes are not limited in any way. For the fringe parking modes, limitations are placed on the length of drive access (40 minutes).

Using the base case scenario and the average attribute variables from the model, the utilities for each of the modes are shown in Table 4-4.

Table 4-4: Average Utility Values for Trips from All Zones to Zone 4

Mode	Utility
Drive Alone	-2.4247
Shared Ride	-3.4327
Walk to Local	-21.0581
Walk to Premium	-25.4113
Drive to Premium	-15.7199
Fringe Park/Walk Egress	-4.2950
Fringe Park/Transit Egress	-4.9544
Fringe Park/Shuttle Egress	-2.5878

Probability

The probability of an individual choosing a mode is based on the utilities of each of the modes. An example of the probability formula for the MNL model was shown in Chapter 3. The probabilities for travel to zone 4 calculated for with the average attribute values are listed in Table 4-5.

Table 4-5: Average Probability Values for HBW trips to Zone 4

Mode	Probability
Drive Alone	40.85%
Shared Ride	14.91%
Walk to Local	0.00%
Walk to Premium	0.00%
Drive to Premium	0.00%
Fringe Park/Walk Egress	6.29%
Fringe Park/Transit Egress	3.25%
Fringe Park/Shuttle Egress	34.70%

Elasticity

The elasticity of an attribute with respect to the output is the effect of the unit change in the value of that attribute on the utility. The elasticity of an attribute is based on the probability of the mode. The direct elasticity for an attribute in the MNL model is:

$$E_n = (1 - P_n)\beta X_n$$

Table 4-6 shows the elasticities for the IVT, OVT and COST attributes of the fringe parking modes.

Table 4-6: Fringe Parking Average Attribute Elasticity

Mode	Elasticity		
	IVT	OVT	COST
Fringe Park/Walk Egress	-0.9991	-1.6164	-0.0775
Fringe Park/Transit Egress	-1.2812	-1.3314	-0.0801
Fringe Park/Shuttle Egress	-0.4655	-0.9448	-0.0430

Table 4-6 shows that all three fringe parking modes are sensitive to changes in the out-of-vehicle time attribute, with walk egress being the most so. Fringe parking with transit egress is the most sensitive to changes in in-vehicle time.

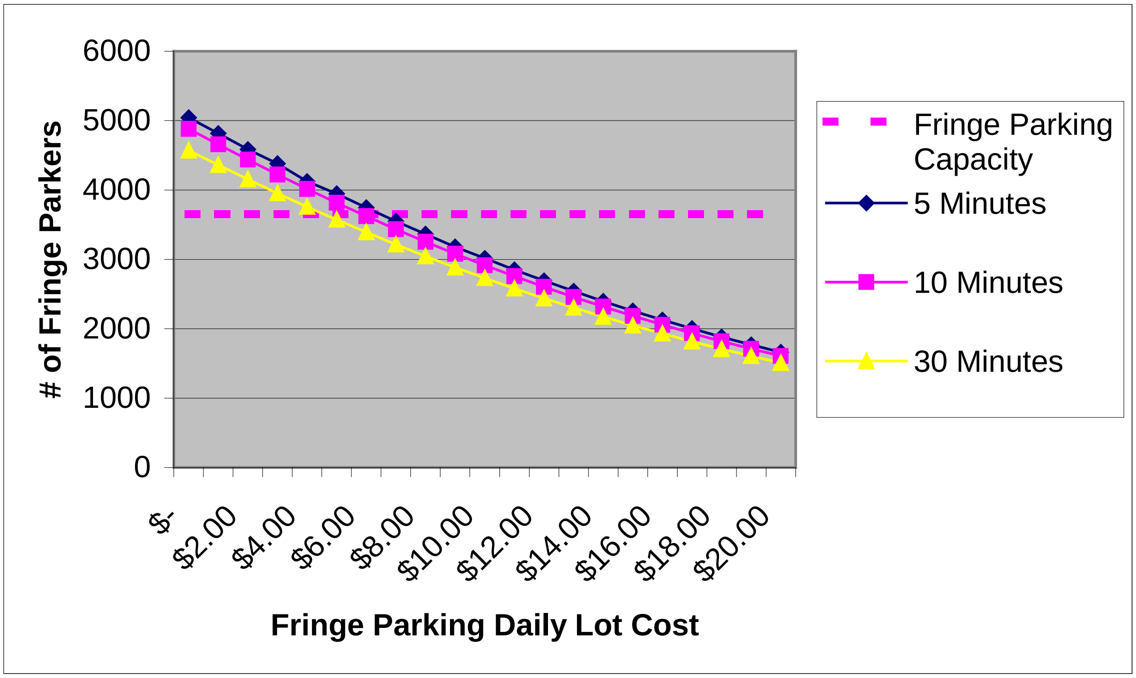
The cost attribute is one that regional policy makers and planners can have the most influence over. The cost for a trip includes the parking or transit cost for the user. Additionally, for any mode that includes an automobile trip, the cost includes the automobile operating cost (10.5 cents per mile). Because of the way the model is designed, there is not a direct way to calculate the elasticity of fringe parking cost. For trips that have a relatively short drive access distance, the fringe parking lot cost is the driving component of the attribute and changes in that cost would have a larger effect on the overall utility than for trips with a longer drive access distance.

Sensitivity Tests

Several sensitivity tests were conducted to show relationships between different variables in the model. The three input variables that were varied were the CBD parking cost, fringe parking cost and fringe parking transit egress headway. All of the tests results are presented in origin-to-destination format.

The first test used the constrained CBD core parking costs that were described in the Methodology chapter. For a range of transit egress headways (5, 10, and 30 minutes), the fringe parking cost was varied in order to determine the optimal cost to attract demand that would meet capacity of the three fringe parking lots. The results are shown in Chart 4-1.

Chart 4-1: Pricing Fringe Parking for Capacity (with constrained CBD core)



There is very little difference in the optimal fringe parking cost for different headways. This may be because the only fringe parking mode that is directly affected by a change in transit egress headway is the fringe parking/transit egress mode. The choice of a fringe parking mode is not sensitive to transit egress only, but the fringe parking egress choice is affected. The change in headway is accounted as part of the OVT attribute. For headways less than 15 minutes, the OVT contribution is half of the headway while for headways greater than 15 minutes, the OVT contribution is 7.5 minutes + 25% of the difference between the headway and 15 minutes. The amount of OVT that comes from walking and access modes possibly plays a larger role.

The next two sensitivity tests show the percentage change in regional mode share when (1) the fringe parking lot cost changes and (2) the CBD core parking cost changes. For both tests, the other parking cost is held at $0. The fringe egress headway is constant at 10 minutes in both tests. Chart 4-2 shoes that percentage change in the regional mode share when fringe parking cost varies from $0-$10/day and Chart 4-3 shows the percentage change in the mode share when the CBD core parking cost is varied from $0-$20/day.

Chart 4-2: Percent Change in Regional Mode Share vs. Fringe Parking Lot Cost

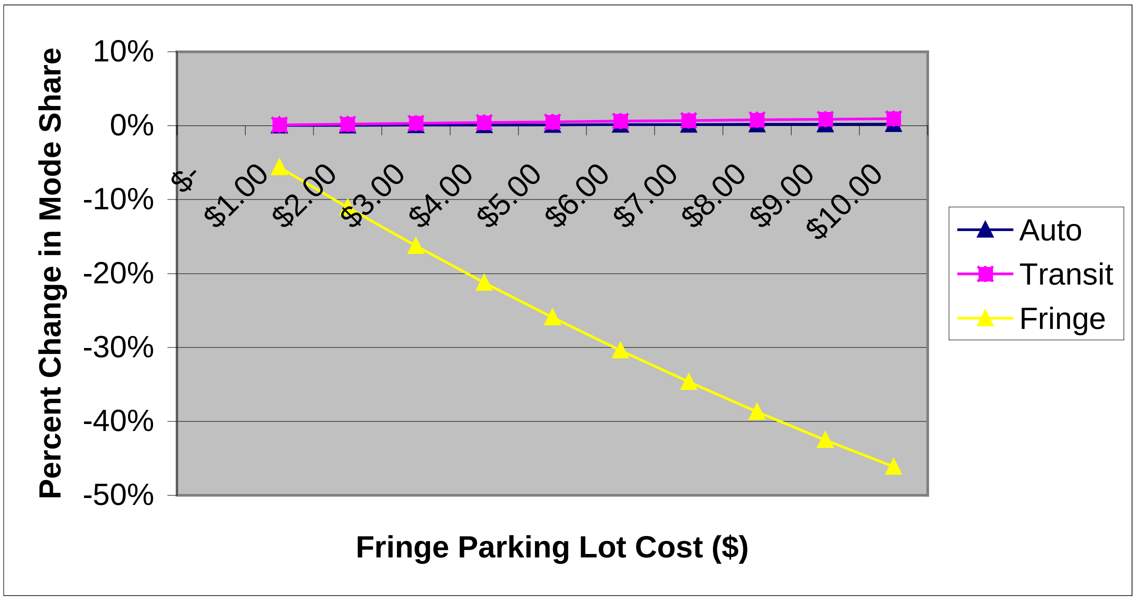
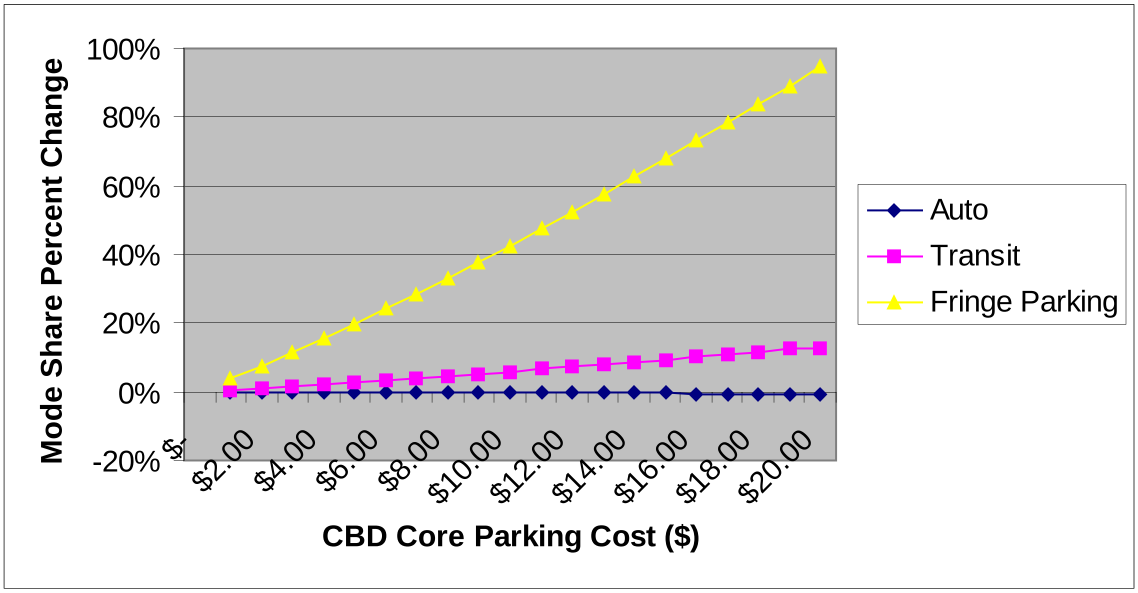


Chart 4-3: Percent Change in Regional Mode Share vs. CBD Core Lot Cost



As fringe parking lot cost increased from no cost to a cost of $10 per day (while CBD core parking remains free), 1,275 out of 2,764 individuals switched away from fringe parking – 1,192 switched to an auto mode and 82 switched to a transit mode. Overall, 3,756 auto trips are lost as CBD core parking climbs from no cost to $20/day (while fringe parking cost remains free). Of those trips, 1,118 trips shift to transit while 2,613 trips shift to fringe parking. The mode shift in the test with fringe parking cost held constant and the test with CBD core parking constant show a similar trend in mode shift. When CBD parking costs are increased, auto users are more likely to shift to fringe parking than transit and similarly, when fringe parking is increased, fringe parkers are more likely to shift to an auto mode rather than transit.

The final two sensitivity tests compare the fringe parking egress mode share to (1) changes in fringe parking lot cost and (2) changes in fringe parking transit egress frequency. In the first test (Chart 4-4), the daily CBD core parking is held constant at

$6.50/day and fringe parking transit egress headway is held constant at 10 minutes while fringe parking lot cost ranges from $0 - $10/day. In the second test (Chart 4-5), the daily CBD core parking cost remains constant, the fringe parking lost cost is held constant at $3.00/day and eight different transit egress headways are tested, ranging from 2.5 min to 60 min.

Chart 4-4: Fringe Parking Egress Choice vs. Fringe Parking Lot Cost

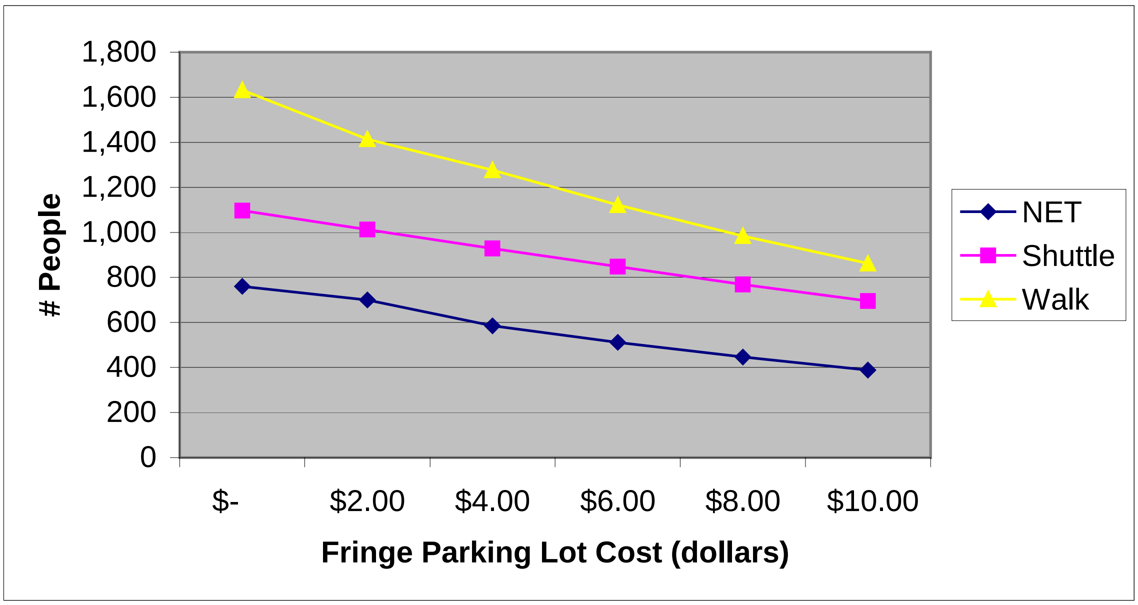


Chart 4-5: Fringe Parking Transit Egress Choice vs. Transit Egress Headway

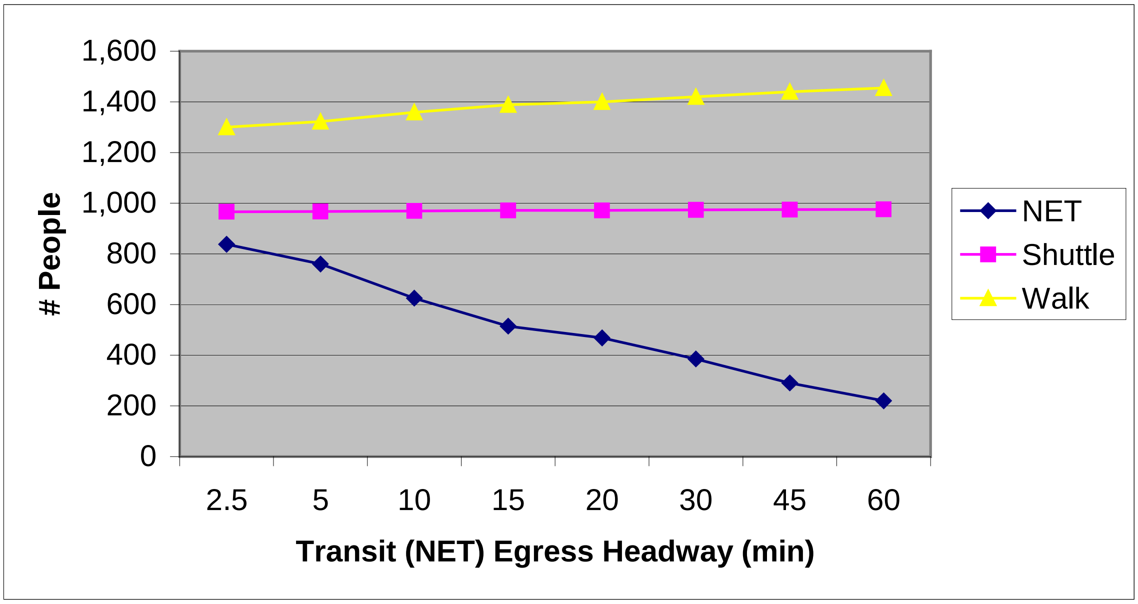


Chart 4-4 shows that all of the fringe parking mode choices are negatively impacted by increased in fringe parking lost costs, as expected. None of the modes appears to be significantly impacted more than any of the others after the initial $2.00 increase. Chart 4-5 shows that the transit egress (NET) headway change most impacts transit egress mode choice. While there is an overall drop in fringe parkers, some of the transit egress parkers shift to walk egress. The increase in transit headway increased the out-of-vehicle time which would reduce that advantage that transit had over walk for some trips. Shuttle egress remains virtually unaffected by changes in transit egress headway. Shuttle egress is already a more desirable choice than transit for most trips going to a zone with shuttle service. The majority of individuals who can take the shuttle already are and those who are shifting away from transit egress as the headway increases cannot switch to the shuttle egress mode. This explains why shuttle service is virtually unaffected by increases in transit headway.

Chapter Five: Conclusion

Fringe parking is a tool that city planners can use to relieve downtown traffic congestion. Fringe parking can also be a solution to limited parking facilities downtown, and an alternative for individuals who are willing to sacrifice convenience for a lower parking cost. A review of literature showed that fringe parking is being studied, but there is still research to be done.

By modeling fringe parking trips within the regional model, fringe parking directly competes with other modes. This provides the ability to report fringe parking trips as part of a regional VMT and air quality.

Identifying fringe parking as a separate mode apart from auto modes and transit park-and-ride modes allows for representation of the unique characteristics of fringe parking users. This research has found that fringe parkers are sensitive to changes in both CBD and fringe parking lot cost. Increases in fringe parking lot cost were more likely to shift fringe parking patrons to an auto mode than transit. Similarly, auto mode users were more likely to shift to fringe parking rather than a transit mode as downtown parking costs increased.

The mode choice model with the fringe parking nest can be used by city and regional planners to study existing and proposed fringe parking lots. Potential applications of the model include studying the relationship between fringe lot and CBD lot pricing, examining the impact of transportation system variable changes on fringe parking, examining impacts of fringe parking variable changes on the rest of the transportation system.

The model as presented has limitations. The model is a regional model and it is debatable as to whether or not it can accurately show small movements in the CBD area.

The model calibration was limited by the research objective of incorporating a fringe parking nest into an existing mode choice model. Incorporating the fringe parking nest in an existing model with mode choice coefficients that meet FTA guidelines may not reflect the mode choice decisions of Hampton Roads area travelers as accurately as possible. Further data collection, possibly in conjunction with the MPO, HRPDC, could provide a basis for determining relationships between attributes.

By creating the mode choice nest within the constraints of an existing model, the fringe parking cost was part of the overall cost variable attribute along with the auto operating cost for the fringe parking modes. This set-up is similar to the auto modes (drive alone and shared ride) where the cost is the auto operating cost and the zonal parking cost. Because fringe parking cost was not an attribute of its own, it was not possible to directly calculate the elasticity of fringe parking cost. Changing the attributes would also require estimating new coefficients.

The data collection had limitations due to time and budgetary constraints. Data were collected for fringe parking lot egress mode and fringe parker origin, but there is no connection between the two pieces of data that would have shown relationships between origin jurisdiction and egress mode choices. Additional data could provide further insight into the decision-making process of fringe parkers.

An aspect of this research that should be further reviewed is the artificial parking price increase described in the methodology chapter to constrain CBD core parking and represent future parking deficits. The additional cost for auto trips removed trips from the CBD core, but more study should be done to determine what happens to the auto trips that had been destined for the CBD core prior to the parking price increase. A similar review should be done if fringe parking lot capacity was also to be constrained by using an artificial increase.

For further study, more data could be collected on fringe parkers via on-site interview or a mail-in survey distributed to fringe parkers. This could identify reasons for fringe parking and the importance of different variables on the decision to use a fringe parking lot. Furthermore, in this research, the model structure and mode choice coefficients were already established and the fringe parking nest was created within those constraints. Further study could identify a different model structure or list of attributes to represent fringe parking.

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