

ABSTRACT

Title of Thesis: REGIONAL PUBLIC TRANSPORTATION
IMPROVEMENTS FOR DISADVANTAGED
USERS: AN INTEGRATED ANALYSIS OF
THE SOCIAL AND TRANSPORTATION
NEEDS OF LOW INCOME POPULATIONS
FOR THE WASHINGTON D.C.
METROPOLITAN REGION

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Public transportation is a crucial part of the economic and social fabric of metropolitan areas. However, transit ridership has been decreasing over the decades, putting preference on the convenience of owning personal vehicles. It is seen that low income individuals are less likely to own a vehicle, thus becoming dependents on the public transportation system. However, there are few studies performed to analyze how effectively transit connects people and jobs within and across these metropolitan areas. And as a result, few federal and state programs related to transportation use factors like job accessibility via transit to make investment decisions. There are even fewer studies and programs relating to subsidizing vehicle ownership.

Analyzing characteristics of low income individuals, understanding travel patterns, job availability, accessibility, and trip chaining are the methods used in this analysis to better understand the transportation needs of low income individuals.

In addition, understanding the relationship that transit and personal vehicles play on the location of low income individuals and low income employment is crucial in creating and implementing programs that will improve and maintain transit and vehicle ownership options for metropolitan residents.

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TRANSPORTATION NEEDS OF LOW INCOME POPULATIONS
FOR THE WASHINGTON D.C. METROPOLITAN REGION

by

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Chapter 1

Transportation Needs of Low Income Individuals

1.1 Introduction

Public transportation is a crucial part of the economic and social fabric of metropolitan areas. However, transit ridership has been decreasing over the decades, with commuters preferring the convenience of personal vehicles. However, studies show that low income individuals are less likely to own a vehicle, thus becoming dependents on the public transportation system. There are few studies performed to analyze how effectively transit connects people and jobs within and across these metropolitan areas. And as a result, few federal and state programs related to transportation use factors like job accessibility via transit to make investment decisions. There are even fewer studies and programs relating to subsidizing vehicle ownership. In addition, understanding the relationship that transit and personal vehicles play in the location of low income individuals and low income employment is crucial in creating and implementing programs that improve and maintain transit and vehicle ownership options for metropolitan residents. Analyzing characteristics of low income individuals, understanding travel patterns, job availability, accessibility, and trip chaining are the methods used in this analysis to better understand the transportation needs of low income individuals.

1.2 Literature Review

1.2.1 Travel Patterns

Numerous studies of the the U.S. Census and National Household Travel Survey (NHTS) were performed to understand the differences in the travel patterns of low income individuals versus higher income individuals. The studies showed that a secular decline in transit demand that started in the 1930s still continues today. This leaves the public transit industry with two major markets: downtown commuters and transit dependents. The downtown commuters still persist due to cost and limited parking availability, road congestion, and large concentrations of jobs that make transit access relatively convenient. Transit dependents are those who are unable or unwilling to drive or do not have access to a personal vehicle [Giuliano et al., May, 2001, Giuliano, 2005]. This transit-dependent market is increasingly an inner city, minority market; however, studies show that this market is shrinking as car ownership continues to increase [Giuliano et al., May, 2001].

According to studies of the U.S. Census data, the use of public transit as the primary transportation mode to work has decreased from 12.6% to 4.7% between 1960 and 2000. During that period, automobile use has increased from 84.1% to 87.9%. There has been an increasing trend in single-occupancy-vehicle commuters and a decreasing trend in high-occupancy-vehicle commuters. According studies of the Nationwide Personal Transportation Surveys (NPTS) and the National Household Travel Survey (NHTS), all person-trips on transit have decreased from 3.2% to 1.6% between 1969 and 2001 [Pucher and Renne, 2003]. The loss of the middle-

and higher-income passengers have been greater than the loss of low income passengers, therefore, low income passengers make up an increasing share of transit users [Giuliano, 2005, Waller, Dec., 2005]. These statistics are summarized in Table 1.1.

Table 1.1: Summary of Trips.

	Percent of Trips in Year	Percent of Trips in Year
Work Commute via Public Transit	Year 1960: 12.6%	Year 2001: 4.7%
All Person Trips via Public Transit	Year 1969: 3.2%	Year 2001: 1.6%
Work Commute via Automobile	Year 1960: 84.1%	Year 2000: 87.9%

Source: Nationwide Personal Transportation Surveys and National Household Travel Survey

Analysis of the 2001 NHTS indicates that low income individuals make fewer trips than those of higher income households. Low income individuals make about 20% fewer trips than people at other income levels (1,340 person trips compared to 1,648 person trips) [Giuliano, 2005, Murakami and Young, Oct., 1997, Pucher and Renne, 2003, Waller, Dec., 2005]. From the 1995 National Personal Transportation Survey (NPTS) data, it was found that the average trips per day ranged from 3.4 trips for those in the lowest income category to 4.2 trips for those in the highest income category [Pucher et al., 1998].

Low income individuals also travel nearly 40% fewer miles than higher income individuals, yet low income individuals have longer travel times, especially for trips that require transfers [Giuliano, 2005, Murakami and Young, Oct., 1997, Pucher and Renne, 2003, Waller, Dec., 2005]. The average miles traveled per day ranged from 17.4 miles for those in the lowest income category to 28.6 miles for those in the highest income category [Giuliano et al., May, 2001]. About 60% of low income individual trips are 3 miles or less compared to 50% for other individuals. This is more apparent in low income single parent households where about 66% of trips

are 3 miles or less. Because vehicle availability is lower, vehicle miles traveled is also lower by 40% compared to other households (9,060 versus 14,926 person miles) [Murakami and Young, Oct., 1997]. The difference between trips made and mileage can be explained in car ownership and modal use [Giuliano et al., May, 2001].

Averaged across all households, commuting to work by private vehicle can take half as long as commuting via other modes – 20 minutes compared to 42 minutes [Waller, Dec., 2005]. Personal automobile are especially advantageous and suitable for multiple-stop trip chaining like taking a child to school, grocery shopping, and other errands that require significantly more time when relying on public transit as the primary transportation mode [Goldberg, 2001, Lucas and Nicholson, 2003, Waller, Dec., 2005].

Though low income individuals are less likely to own a vehicle, they still make a majority of their trips in private vehicles. These trips are much more likely to be made using a vehicle owned by someone else, like a friend or relative at a rate of 8% compared to 1% for other income groups. This percentage is higher for households with children [Murakami and Young, Oct., 1997].

Data from NHTS 2001 show that car ownership dramatically decreases public transit usage from 19.1% for households with no vehicle to 2.7% for households with one vehicle [Pucher and Renne, 2003]. Instead of taking public transit, a large percentage (43.5%) of individuals use non-motorized (i.e., walking and biking) trips. Individuals with access to a vehicle sacrifice mobility by having to rely on public transit and non-motorized trips, resulting in shorter and fewer trips. For work and work-related trips, low income households reported 5% walk modal share compared

to 3% for other income groups [Murakami and Young, Oct., 1997].

Low income individuals are also more likely to take public transit to work with 5% modal share compared to 2% for other income groups [Murakami and Young, Oct., 1997, Waller, Dec., 2005]. Low income individuals are more likely to take bus transit, whereas other income level individuals are more likely to take rail transit. Therefore, the average trip distance for low income households using public transit is 10 miles compared to 13 miles for other income levels. Associated with the shorter trip is a shorter commute time, 36 minutes for low income households compared to 43 minutes for other households [Murakami and Young, Oct., 1997]. These statistics are summarized in Table 1.2.

Table 1.2: Summary of Trips Made by Low Income and Other Income levels.

	Low Income	Other Income Levels
Vehicle Ownership	73.5%	96.0%
Vehicles per Adult	0.7	1.0
Average Age of Vehicle	10 years	7.3 years
Person Trips (Per Day)	3.4 trips	4.2 trips
Person Trips (Per Year)	1,340 trips	1,680 trips
Average Miles Traveled (Per Day)	17.4 miles	28.6 miles
Trips 3 Miles or Less	60%	50%
Trips Made via Automobiles Owned by Others	8%	1%
Trips via Walking	5%	3%
Work Commute via Walking	5%	3%
Work Commute via Public Transit	5%	2%
Average Miles on Public Transit (Per Day)	10 miles	13 miles
Average Commute Time on Public Transit	36 minutes	43 minutes

Source: National Household Travel Survey, 2001

1.3 Impact of Transportation on Accessibility

Studies have shown that increased mobility can positively affect employment status for low income individuals. Although policy makers tend to want to subsi-

dize transit, there is little empirical evidence that supports increasing public transit mobility positively effects employment status [Sanchez et al., 2004]. Sanchez, Shen, and Peng [2004] examined whether increased transit access is associated with the employment status of Temporary Assistance for Needy Families (TANF) recipients in six metropolitan areas. A limited dependent variable regression analysis was performed and the results indicate that access to fixed-route transit and employment locations had virtually no association with employment outcomes of TANF recipients [Sanchez et al., 2004].

Numerous studies attempt to address the relationship between labor force participation and the spatial separation of jobs and houses; however, most analyses concentrate on commuting time or distance as a function automobile accessibility. Few studies consider the relative impacts of employment accessibility resulting from public transportation services. Various studies have recognized that traditional public transportation services have limited capacity to meet the travel needs of persons with little or no access to automobiles [Sanchez, 2008].

Shen [1998] examined the impact of public transit on connecting urban residents with job locations using labor participation rates (average annual weeks worked, as reported by the 1990 U.S. Census). The analysis was performed on Portland, Oregon and Atlanta, Georgia residents living within walking distance (i.e., quarter of a mile) and not within walking distance of a transit stop. Census block groups were examined and for all block groups, average employment levels decreased as the distance from transit stops increased. Average employment levels were found to increase substantially as vehicle ownership increased. The results partially sup-

port policies for improving public transit access to improve urban employment.

1.4 Current Transportation System

City residents and lower-income neighborhoods tend to be better served by transit than residents of suburbs and middle/higher-income neighborhoods [Tomer et al., May, 2011]. Therefore, public transportation systems have been the response of upper-income groups (business owners) to the mobility needs (demand) of lower-income groups and the notion that transportation mobility is important for economic opportunity. There is little evidence suggesting that the public transportation system development resulted from lower-income groups [Sanchez, 2002]. Hence the primary mode of public transportation is fixed bus route service where riders must adapt to service availability [Sanchez, 2008].

Although, nearly half of all work commutes still originate from or terminate in central cities, 39% of work commutes are entirely suburban, that is originating and terminating in suburban areas. Older rail transit systems fail to capture most suburban commuting patterns because they were mostly developed for trips into and out of the city. This hub-and-spoke transit pattern provides dense metropolitan cores, but may not serve other metropolitan areas very well. From 2002 to 2007, the amount of developed land in the US increased by 8.4%, nearly twice the rate of population growth (4.5%). A majority of large metropolitan residents live under traditional or exclusionary zoning requirements that separate different land uses and/or emphasizes low-density development, thereby making it harder to connect

people and jobs using public transportation alone [Tomer et al., May, 2011].

The Brookings Institute performed a large scale accessibility study on the top 100 largest metropolitan areas across the U.S. They found that nearly 70% of U.S. Census defined block groups have access to at least one transit stop within 3/4 mile of their population weighted centroid. Transit coverage is best in Western metropolitan areas and worst in Southern metropolitan areas. In the Northwest and Midwest, neighborhoods that developed decades before the adoption of automobiles have neighborhoods that are well-served by public transit [Tomer et al., May, 2011].

The service frequency is calculated as the median of typical headways in all block groups with public transit access, weighted by their working-age population. Typical headways are shown in Table 1.3. Good transit service does not necessarily equate to high service frequency. Some metropolitan areas have short headways, but focus on smaller areas, thus the area overall has poor transit coverage. In cities, low income neighborhoods experience shorter headways than high-income neighborhoods. Transit systems provide service to city residents nearly twice as frequently as suburban residents (94% versus 58%). This reflects built up transit and rail systems prior to suburbanization, thus serving cities better than suburbs. Within metropolitan areas, city headways are consistently shorter than suburban headways [Tomer et al., May, 2011].

The Brookings Institute found that typical metropolitan residents can reach about 30% of jobs within their area via public transit in 90 minutes. Metro-wide job access was calculated as the average share of jobs reachable within 90 minutes across all block groups with transit coverage, weighted by block group working-age

population. This varies considerably across metropolitan areas reflecting variable transit coverage levels, service frequencies, employment levels, and population decentralization. The percentage of jobs accessible via transit in 90 minutes by region is listed in Table 1.3. In all regions, city residents have better transit access to jobs than suburban residents. The biggest disparity is seen in the north-east, and in the mid-western and southern suburbs, the accessibility level is below 20%. Low income neighborhoods have higher job accessibility than other income levels (36% for low income level, 28% for middle income level, and 23% for higher income level) [Tomer et al., May, 2011]. However for most individuals, a 90 minute commute on public transit is very costly in terms of time and other social factors such as comfort and convenience that is preferred in private automobiles [Sanchez, 1999].

Table 1.3: Public Transit Service Performance for Different Metropolitan Regions.

Metropolitan Region	Transit Service Headway (During Peak Hours)	Job Accessibility (for 90 Minute Public Transit Travel Time)
North-East	8 minutes	32%
Western	9.2 minutes	33%
Mid-West	11 minutes	28%
Southern	12 minutes	26%

Source: Brookings Institute [Tomer et al., May, 2011]

1.5 Public Practices

There are various current practice transportation policies and programs implemented to promote job accessibility and accessibility to medical, government, and other necessary services and locations for low income peoples, elderly, disabled, and otherwise disadvantaged population. From an external point-of-view these im-

plemented programs have helped thousands of disadvantaged individuals find and maintain jobs, get necessary access to medical facilities, help and promote a more efficient everyday life. However, there are few empirical studies performed to analyze the effectiveness of these programs.

These programs range from: paratransit services, carpool/vanpool type services, assistance and subsidization of car ownership, subsidized public transit, etc. The following sections will provide case studies of implemented transportation policy practices and program to increase the understanding of different possible policies and programs that may be introduced into the Washington D.C. Metropolitan Region. Potential programs will be recommended for the region based on the urban and suburban effective regions that require attention.

Though the region of interest would not be designated as rural, there are many transportation programs that are recommended which can be modified to be more effective in suburban areas, therefore these initiatives should not be readily dismissed.

1.5.1 Subsidized Public Transportation

Subsidizing public transit has two conflicting objectives: 1) to provide a basic level of mobility for all persons, but especially to those disadvantaged, and 2) to provide an effective substitute for personal vehicles in order to reduce automobile travel and its associated consequences, including: traffic congestion, air pollution, and urban sprawl [Giuliano et al., May, 2001, Hodge, 1995]. The latter objective has

emphasized the provision of rail transit, which is more attractive to discretionary riders and therefore more effective in achieving environmental goals. Also, with the smart growth movement, even more emphasis has been placed on rail transit [Giuliano et al., May, 2001].

Transit investments manifest the emphasis on rail transit. Between 1991 and 1998, the total revenue vehicle miles of light rail, commuter rail, and heavy rail service increased 59, 20, and 8 percent respectively. Over the same period, bus service increased by only 6 percent [of Transportation, 1998]. There is little evidence that suggest that these investments are generating the desired increases in transit ridership. And in some cases, new rail service replaces pre-existing bus route service and attracts few new riders from cars. New rail systems appeal to long distance, downtown commuters, who are disproportionately affluent. Often enough, the high cost of building and operating rail systems have led to reducing transit ridership as fares increase and bus service is reduced in response to budge constraints. Low income individuals concentrated in central cities would benefit more from increased bus service frequency, lower bus fares, and fewer bus transfers [Giuliano et al., May, 2001].

Mobility is essential for access to jobs, services, and social activities, therefore it is seen as a public responsibility to supply basic levels of transportation services to those who do not or cannot drive. Public transit agencies have shifted resources from basic local transit services to more costly commuter services designed to attract discretionary riders. Since the local transit services are used more by low income individuals, the benefits of other commuter services are not seen by these individuals,

therefore the public subsidies are inequitably distributed [Hodge, 1995]. The housing near the rail transit is also becoming more expensive, making it difficult for low income households to reside near the rail transit system [Giuliano, 2005, Waller, Dec., 2005].

Despite significant investment and public subsidies in public transit network, transit usage as a whole is on the decline. Nationwide travel survey data show that less than 2% of all person trips are made by public transit [Giuliano, 2005, Giuliano et al., May, 2001]. The trend is to cut central city transit investment and put it towards suburban commutes (rail and discretionary riders) [Waller, Dec., 2005]. US transit ridership is heavily concentrated in a few of the largest cities. New York City accounts for 40% of US daily transit ridership, when adding Los Angeles, Chicago, Boston, San Francisco, and Washington DC, these cities account for two-thirds of the nations total daily transit ridership [Association, 2000].

In Lincoln/Lancaster, Nebraska [Boesch, May, 2005], a six month pilot project was launched to test the hypothesis that decreasing cost would increase ridership. From October 1, 2004 to March 31, 2005, Human Services and StarTran jointly operated the program in efforts to increase ridership on the Citys busses and Handi-Vans, thus proving more affordable transportation to low income individuals. Bus and Hand-Van passports were subsidized making bus passports \$5 per month (originally \$30 per month) and Handi-Van passports \$10 per month (originally \$60 per month).

Over the six-month pilot program, ridership continued to increase from 692 low income passports in October to over 1,200 passports each month. Ridership

increased by 25% in youth riders each month and was evenly split between males and females. Ridership increased by 15.2% from the previous year. An estimated additional 1,000 people are using public transportation on a regular basis. Rider surveys indicate that 60% use the bus to get to work and 70% use the bus system as their primary transportation mode. The Handi-Van had a 6.5% total increase in ridership.

1.5.2 Paratransit

Within Virginia, Richmond has taken initiative to provide the elderly, disabled, and low income individuals access to transportation. In 2000, the U.S. Census reported that approximately 12% of the U.S. population is below poverty and within Virginia, almost 10% of its residents are living below the poverty level. The Richmond area has 64,000 people (age 5 years and older) living below poverty, amounting to 9% of the regions population. Over half of these low income peoples live within the City limits. Therefore to address these concerns, transportation programs and services have been implemented to increase the mobility of low income individuals.

The Goochland Fellowship and Family Services (GFFS) [Feb., 2006] provides free transportation services to its residents who cannot otherwise provide transportation for themselves due to age, disabilities, or poverty. GFFS employs one full time van driver which provides transportation with one handicapped accessible van to medical and dental appointments and for pharmaceutical needs. Reservations are requested to be made 24 hours in advance and the service runs during weekdays.

During 2005, GFFS provided transportation to 649 individuals and made 201 trips to medical and dental appointments and to local pharmacies.

Another vanpool paratransit transportation program initiated in Richmond, VA is Access Chesterfield (in Chesterfield County, Virginia). It is coordinated vanpool transportation program for the disabled, elderly (age 60 and over), and those who meet federal income guidelines, where household income is less than 200% the poverty level. The vanpool service has no limit on the trip purpose within the service area as long as it remains in the service area. Services are made by reservation only from Monday through Saturday. The cost is two vouchers for any trip regardless of distance, where a pack of 10 vouchers is \$25. The average weekly trips have increased from several trips to almost 300 trips per week during the November 2004 to June 2005 observation period.

1.5.3 Subsidized Vehicle Ownership

The share of households without vehicles dropped from 21% in 1969 to 9% in 1995. The majority of zero-vehicle households are the elderly and retired persons. Most of the remainder is single individuals without children, and two-thirds of zero-vehicle households have no workers. Low income households are less likely to have a vehicle, largely in part because a greater portion of their income is spent on shelter and food. 8% of all urban households do not have a car. However, for households with an annual income less than 20,000, 26.5% do not have a car compared to 4% of other households [Murakami and Young, Oct., 1997, Pucher and Renne, 2003,

Waller, Dec., 2005].

Though low income individuals are less likely to own a vehicle, 84% of work trips in low income households use private vehicles compared to 90% in other households. However, the average age of the car for low income individuals is also higher than other households, 10 years compared to 7.3 years. Within low income households, there is 0.7 vehicles per adult compared to 1 vehicle per adult in other households [Murakami and Young, Oct., 1997, Waller, Dec., 2005]. Low income individuals also tend to pay more when purchasing and financing a vehicle, possibly attributable to bad, short, or no credit history. For those who do own a vehicle, insurance payments and ongoing maintenance costs, especially for older vehicles), are often very high [Goldberg, 2001, Lucas and Nicholson, 2003, Waller, Dec., 2005]. The total car ownership cost varies from region to region, but is generally between \$1,100 to \$1,400 per year (excluding purchase price and any major repairs). For a low income individual working earning minimum wage and working less than 40 hours per week, this \$1,100 to \$1,400 cost can fall between 10 to 14 percent of their income [Goldberg, 2001].

The research by Ong and Blumberg [1998] showed that the labor market does not generate compensating wages for welfare recipients who travel far distances to work, such that wages are negatively associated with distance [Wachs and Taylor, 1998]. Therefore better geographical job access has both direct and indirect effects on recipients. Out-of-pocket expenses are reduced and the opportunity costs associated with travel to work is reduced when the geographical access is improved. Because the labor market does not produce compensating wages for long distance

commutes, improved access to jobs indirectly affects recipients through increased earnings. The findings stress the importance of increasing job access through local economic development and by improving mobility, both housing mobility and transportation mobility, among low income individuals [Ong and Blumberg, 1998].

Vermont is primarily a rural state with over 60% of its population living in rural areas. There are only a few towns in Vermont with a public transportation system. The public transportation systems that are available do not provide the necessary mobility for low income individuals to find and retain jobs. The Good News Garage was then created in 1996 to facilitate the ownership of functional vehicles by low income individuals, with the focus and objective of helping them find and retain employment.

The Good News Garage (GNG) program acquires vehicles from donors, repairs or refurbishes them, and sells them at minimal cost to individuals with income less than 150% of the poverty level. Priority is given to applicants who need a vehicle to retain their current employment or those who are participating in a job training program. The program calls for a personal contribution of \$400 to \$800 to cover some of the costs of repairs or refurbishing, vehicle registration, and taxes. Since its start in 1996, the GNG has provided over 1,000 donated cars to low income Vermont residents.

An analysis of the effectiveness of the program found that mean earned income was \$220 higher per month after individuals received the vehicle (\$361.40/month after receiving the vehicle compared to \$141.90/month prior). Lucas and Nicholson [2003] studied the impacts of vehicle acquisition using reduced-form random effects

and censored regression models to account for other factors, such as the simultaneous decision to work and to participate in the welfare program. The impacts of the vehicle acquisition program were still found significant in increasing the probability of employment. The researchers found that income increased between \$124 (using random effects model) and \$127 (using censor regression model) per month due to car ownership. Individuals were also 19% more likely to have earned income after acquiring a car. The car cost to the individual and the program would be recovered within a few months as earnings replaced welfare cash assistance [Lucas and Nicholson, 2003].

1.6 Spatial Mismatch Hypothesis

For metropolitan regions with highly dense city centers and expanding suburbs like the Washington D.C. Metropolitan region, there is a tendency for a spatial mismatch between where low income individuals reside and where low income jobs are expected to grow. Central city residents experience high unemployment even in times when the overall demand for labor is high. Traditional explanations are: inferior quantity and quality of education, poor health, and low motivation of low income individuals [Kalachek, 1968]. A majority of low income households reside in rural areas and central cities. And within the last century, residential and employment patterns have in metropolitan areas have reversed [Murakami and Young, Oct., 1997, Wachs and Taylor, 1998, Waller, Dec., 2005]. Also, basic amenities are increasingly located in the suburbs; therefore access to transportation is limited for

low income individuals [Criden, 2008, Murakami and Young, Oct., 1997, Waller, Dec., 2005].

The spatial mismatch hypothesis stresses the spatial separation between the central-city residential locations of low income individuals and expanding job opportunities in the suburbs and the long commute that is needed to connect them [Blumberg, 2004, Blumberg and Manville, Nov., 2004, Criden, 2008, Giuliano, 2005, Tomer et al., May, 2011, Wachs and Taylor, 1998]. A study by Kasarda [1995] found that 70% of all jobs in manufacturing, retail, and wholesale industries that typically have large number of entry level jobs are located in the suburbs. Much of the job growth within cities requires higher skill levels that many low income workers dont have [Criden, 2008, Kalachek, 1968, Murakami and Young, Oct., 1997, Tomer et al., May, 2011, Waller, Dec., 2005].

There are higher concentrations of high-skill industries located within cities than low- and middle-skill industries. About a quarter of low- and middle-skill industries are accessible via public transit in 90 minutes compared to a third of high-skill industries. 94 of the top 100 metropolitan areas provide greater public transit access to high-skill industries than low- and middle-skill industries [Tomer et al., May, 2011]. As low-wage jobs are emerging further and further away from central cities, many low income workers have difficulty accessing jobs, training, and other services such as childcare due to inadequate transportation options [Criden, 2008, Kalachek, 1968, Murakami and Young, Oct., 1997, Waller, Dec., 2005]. While new jobs are located in the suburbs, there is little public transit that connects the central-city low income residents to suburban employment [Organization, Feb.,

2006, Waller, Dec., 2005]. Therefore the low income workers experience a relative decline in job accessibility, which leads to higher unemployment rates and longer commutes for those employed in the suburbs, which imply lower net wages [Giuliano et al., May, 2001, Giuliano, 2005]. The rapid increase in suburban employment does not mean entry-level jobs no longer exist in central cities. Net job growth and job turnover in existing jobs needs to be distinguished, and there is plenty of evidence that suggests that urban job turnover rate actually exceeds the rate of suburban job growth [Blumberg and Manville, Nov., 2004]. As urban sprawl increases around the country due to the adoption of automobiles and the development of auto-dependent societies, the transportation mode choices share of walking and biking decreases and the reliance on automobiles increase [Criden, 2008].

A study by Ong and Blumberg [1998] showed that welfare recipients who lived in job-rich neighborhoods are more likely to find work in close proximity to their home than those who lived in job-poor neighborhoods. The job distance model emphasized the importance of creating employment opportunities in neighborhoods where jobs are scarce.

During the 2000s, poverty grew five times faster in the suburbs than in cities. While low income households in the suburbs are not nearly as geographically concentrated as some central cities low income neighborhoods, there is a trend towards suburbanization of poverty. Low income suburban residents also tend to live in less job-rich communities than their higher income counterparts [Tomer et al., May, 2011]. The isolation of inner-city and unemployed persons from suburban employment opportunities was identified many years ago and from a transportation

perspective, the reverse commute presents a significant challenge for low income individuals because many do not own a vehicle and transit service does a poor job of servicing these types of reverse commute trips [Sanchez et al., 2004].

An argument against the spatial mismatch hypothesis include the notion that low income individuals do not have a geographical disadvantage with respect to job opportunities, rather, many of them suffer from a spatial disadvantage because they are dependent on relatively slow, inflexible, and limited public transit services [Sanchez et al., 2004].

1.7 Motivation

The existing transportation system cannot always bridge the distance between where low income individuals live and where jobs are located. The existing systems were originally established to transport inner-city residents to city locations and bring suburban residents to central city work locations. However, the majority of entry-level jobs that low income individuals are likely to fill are located in the suburbs which may have limited or no accessibility through the existing public transportation system. The isolation of inner city and underemployed persons from suburban employment opportunities was identified as the poverty transportation problem. The reverse commute experienced by low income individuals who travel from a central city region to a suburban region in the morning and returning in the evening represents a significant challenge for individuals who do not own personal automobiles and rely on public transit because public transit services do a poor job

in serving these types of trip [Sanchez, 2008]. Therefore this research shines light on who low income individuals are, where they live, where they work, what they do, how they travel, and the effect of implementing certain policies on accessibility.

Chapter 2

Statistical Analysis of Low Income Households and Individuals

2.1 Low Income Statistics

A demographic profile of the Washington D.C. Metropolitan Region was analyzed to identify the main characteristics of the low income population, the composition of low income households, and the factors that hinder the advancement of these households using the American Community Survey 2006-2010, 5-year estimates.

2.1.1 Data

The American Community Survey (ACS) 2006-2010 5-year estimates was used to analyze the demographic profile and the location of low income individuals and households. The data are aggregated at the Public Use Microdata Areas (PUMAs) level. The ACS provides information of 293,492, 785,361, and 895,776 households in Washington, D.C., Maryland, and Virginia, respectively. A general reference of the PUMA locations is show in Table 2.2. It should be noted that PUMAs vary in shape and size; hence encompassing different communities. Household and individual weights provided by the ACS were also used to reduce sampling bias and error. The sampling bias includes over and under represented subpopulations.

Low-income households are identified as households with whose total income is below 1.5 times the 2010 National Poverty Guidelines for the respective household

size. These guidelines are updated each year and issued in the *Federal Register* by the Department of Health and Human Services (HHS), see Table 2.1.

Table 2.1: 2010 Poverty Guidelines for the 48 Contiguous States and the District of Columbia.

Persons in Family/Household	Poverty Guideline	Low Income Threshold
1	\$10,830	\$16,245
2	\$14,570	\$21,855
3	\$18,310	\$27,465
4	\$22,050	\$33,075
5	\$25,790	\$38,685
6	\$29,530	\$44,295
For families with more than 6 persons, add \$3,740 for each additional person.		Additional \$5,610

Table 2.2: PUMAs within the Washington D.C. Metropolitan Region.

State	County	PUMA	Reference Location
D.C.		00101	North-West D.C.
		00102	Northern D.C.
		00103	North-East D.C.
		00104	South/South-East D.C.
		00105	Downtown D.C.
MD	Frederick	01001	Columbia
		00300	Fredrick
	Montgomery	01002	Germantown
		01003	Gaithersburg
		01004	Bethesda, Potomac
		01005	Aspen Hill, Rockville
		01006	Coltsville
		01007	Silver Spring
	Prince George	01101	College Park, Hyattsville
		01102	Bowie, Crofton
		01103	Landover
		01104	Walker Mill, Kittering
		01105	Harwood, Davidsonville
01106		La Plata, Huntingtown	
	01107	Suitland	
VA	Arlington	00100	Arlington
	Alexandria	00200	Alexandria
	Fairfax	00301	Fairfax, McLean
		00302	Mt. Vernon
		00303	Burke
		00304	Clifton, Centerville
		00305	Reston, Great Falls
	Prince William	00501	Warrenton, Bristow
		00502	Dale City, Montclair
	Loudon	00600	Gainesville

2.1.2 Low Income Household Statistics

Washington, D.C. has the highest percentage of low income household in the area, with approximately 18.9%. Maryland has the second highest number of low income households at 9.4%. Virginia has the lowest percentage of low income households at 7.4%. Tables A.1 to A.3 in Appendix A shows the distribution of the

percentage of low income households by PUMA.

Within Washington D.C., the central and south-east regions (PUMAs 00105 and 00104) have the overall highest percentage of low income households, 24.1% and 21.9%, respectively (out of all low income households within Washington D.C.). Of all individuals in the south-east region (PUMA 00104), 17.9% of households are low income households. 41.3% of all low income households in Maryland are located in Prince George's County. Within Prince George's County, 19% of households in the College Park area (PUMA 01101) are considered low income. Virginia has the least number of low income households, with a more even distribution of low income households. Overall, there is no PUMA that contains more than 9% of low income households within it. Fairfax County has 46.6% of all low income households within Virginia.

2.1.2.1 Labor Force Distribution of Low Income Households

Understanding the low income household employment composition can help better understand factors that hinder low income households from achieving increased income. ACS defines the labor force as all individuals above the age of 16 and has no illness or condition that prevents him/her from working. ACS breaks down employment status into: at least one member is in the labor force, a household that is described as a couple where neither are in the labor force, a single female as the head of the household whom is not in the labor force, and a single male as the head of the household whom is not in the labor force. Figure 2.1 shows the

breakdown of the employment status of only low income households in Washington D.C., Maryland, and Virginia. Overall, low income households in Washington D.C. have a lower employment rate than those in Maryland and Virginia. However, Washington D.C. has the lowest percentage of households which consist of a couple where neither are in the work force. There is also a larger percentage of single females as head of the household whom are not in the labor force than single males, with the largest overall percentage found in Washington D.C., which in both cases is very concerning. Single female head of households are typically unemployed single mother households. The labor force distribution by PUMA can be seen in Tables A.4 to A.6 in Appendix A.

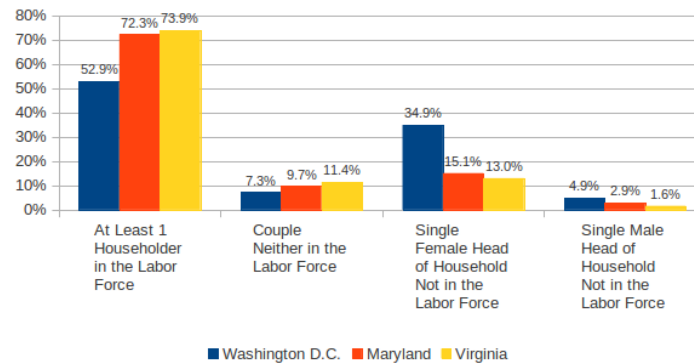


Figure 2.1: Labor Force Distribution of Low Income Households.

Source: American Community Survey 2006-2010, 5-year Estimates

2.1.2.2 Distribution of Low Income Household Size

Figure 2.2 shows distribution of the size of low income households. Surprisingly, more than 50% of households consist of only one person in Washington D.C. and over 40% in Maryland and Virginia. Tables A.7 to A.9 in Appendix A shows

the distribution of low income household size by PUMA.

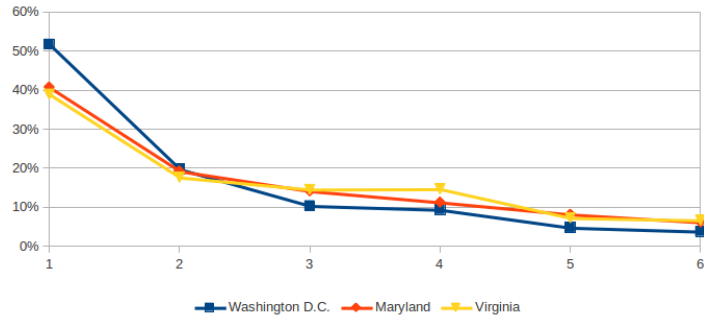


Figure 2.2: Distribution of Low Income Household Size.

Source: American Community Survey 2006-2010, 5-year Estimates

2.1.2.3 Income-to-Rent Ratio

Figure 2.3 shows the distribution of the income-to-rent ratio. It is alarming to find that approximately 38% of all low income households within the region spend more than 100% of their household income on rent. This can be the result of having numerous low income households that consist of one member, high unemployment rate, and high rental rates in the Washington D.C. Metropolitan area. It should be noted that only rental units were observed which consist of 81% of low income households in Washington D.C. and 61% of low income households in Maryland and Virginia. Tables A.10 to A.12 in Appendix A shows the distribution of low income income-to-rent ratio by PUMA.

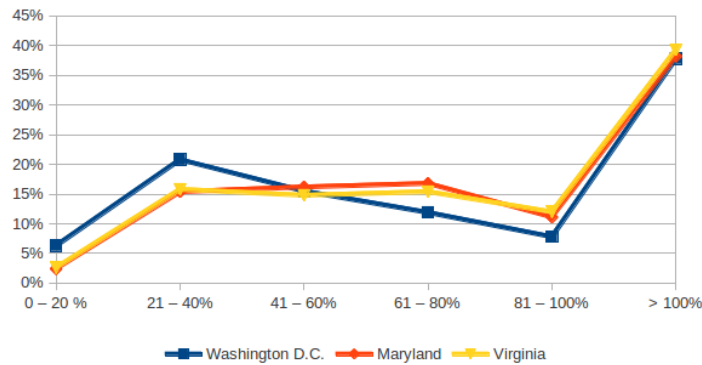


Figure 2.3: Income-to-Rent Ratio of Low Income Households.

Source: American Community Survey 2006-2010, 5-year Estimates

2.1.3 Low Income Individual Statistics

The distribution of low income individuals within Washington D.C. is clustered around the south-southeast portion of Washington D.C. (34%). Within the Maryland portion of the region, the highest percentages of low income are seen in Frederick and College Park (10% and 14%, respectively) with a more uniform distribution in other areas. The low income population is more uniform and at a lower percentage in the Virginia.

2.1.3.1 Labor Force Participation of Low Income Individuals

Figure 2.4 shows the percentage of the low income persons that is economically active. From the ACS defined labor force, approximately 22% to 30% of the low income persons cannot work. It is apparent that low income individuals in Washington D.C. are worse off than those in Maryland and Virginia. The low income individuals in Washington D.C. have the lowest employment rate, highest unem-

ployment rate, and highest rate of individuals not in the labor force. Tables ?? to ?? in Appendix A shows the distribution of labor force participation of low income individuals by PUMA.

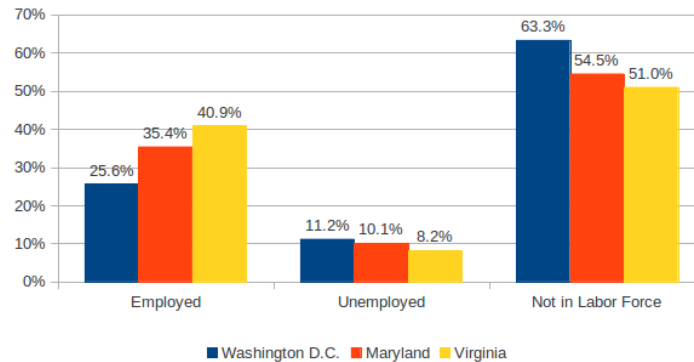


Figure 2.4: Labor Force Participation of Low Income Individuals.

Source: American Community Survey 2006-2010, 5-year Estimates

2.1.3.2 Age Distribution of Low Income Individuals

When decomposing Washington D.C.s low income population by age, it is found that 53% of these individuals are between 16 and 25 years old. Larger percentages can be found in Northwest D.C. and Central D.C (75% and 43%, respectively). This can be expected from a young population that hasnt yet progressed into the labor force thus their low income status. Nevertheless, this highlights a problem of a possible future low income middle aged and elderly population if no measures are taken to guarantee minimal professional and personal progress to the young population. In Maryland, nearly half (51%) of low income individuals are between 16 and 25 years old. The middle aged and elderly (i.e., 36 years and older) low income individuals are more uniformly distributed in Virginia.

2.1.3.3 Education Level of Low Income Individuals

Numerous studies have shown the correlation between education and income level. Data from the U.S. Bureau of Labor Statistics shows that in 2010 the median earnings increase at every level of education. Within the region, around 57% of the low income population attained at the most a high school diploma. Within the east-southeast portion of D.C., nearly 80% of low income individuals completed high school or less. Within Maryland, the percentage range of low income high school graduates or less range from 35% to 75%. Within Virginia, the range is 44% to 75%.

2.2 Low Income Households and Individuals Conclusions

Larger clusters of low income individuals and households are found more in Washington D.C. and Maryland than in Virginia, where the low income population are somewhat uniformly scattered across the PUMAs. Around 40% to 50% of low income households consist of one person. Consequently, their living expenses rise, as demonstrated by the fact that approximately 60% of low income households reported spending more than 80% of their household on rent. Another concerning finding was that 35% of all low income households in Washington D.C. have an unemployed single female as head of the household.

In terms of work, around 10% of low income population was unemployed and 50-60% was not part of the labor force in the year before the survey. This could be a key reason why these people are not rising over the low income threshold. Education can also be a big factor; however, a fair percentage of individuals obtained an

associate's degree or higher. This raises the question of what is impeding low income households from advancing. Future studies should focus on finding the underlying factors (e.g., accessibility to jobs, personal/family commitments, health condition, etc.) that are hindering this demographic. Furthermore, future researchers should consider creating a tailored survey to obtain information that is not usually found in publicly available data sets.

Chapter 3

Low Income Employment Analysis

3.1 Low Income Employment Analysis

A statistical analysis of the Washington D.C. Metropolitan Region is performed to examine the types of jobs held by workers within low income households using the American Community Survey 2006-2010, 5-year estimates along with Round 8a Cooperative Forecast Data from the Metropolitan Washington Council of Governments.

3.1.1 Low Income Employment Data

The same American Community Survey (ACS) 2006-2010 5-year estimates were used and low income households are identified in the same way as the previous chapter to look at the types jobs that low income individuals hold. In this chapter, individuals who live in Washington D.C., Maryland, or Virginia and work in the Washington D.C. Metropolitan Region were analyzed.

The employment analysis was performed on 134,559 individuals living within Washington D.C., Maryland, and Virginia that work within the region from the Public Use Microdata Sample (PUMS). When taking into account weights, there is employment data on 2,772,892 workers in the region. Of those individuals analyzed, 26.4% (731,328) work in Washington D.C., 31.3% (867,043) work in the Maryland

portion of the region, and 42.4% (1,174,521) work in the Virginia portion of the region. The data are aggregated at the county level therefore the data are not at the desired disaggregate level however it is useful to see the general employment and job availability of the region. Table 3.1 shows the percent distribution of where individuals work and reside. Workers in Washington D.C. show the largest share of working outside of where they live.

Table 3.1: Percent Distribution of Where Individuals Work and Live.

Reside In	Work In		
	Washington D.C.	Maryland	Virginia
Washington D.C.	28.2%	42.7%	29.1%
Maryland	4.3%	89.6%	6.1%
Virginia	2.9%	10.2%	86.8%

Source: American Community Survey 2006-2010, 5-year Estimates

3.1.2 Low Income Employment Analysis by Jurisdiction

Figure 3.1 shows the percent of low income workers out of the total number of all low income workers within the region. 24.8% of *all* low income workers in the entire Washington D.C. Metropolitan region are found within the District of Columbia. Large percentages of low income workers are also found in: Montgomery, Prince George's, and Fairfax County.

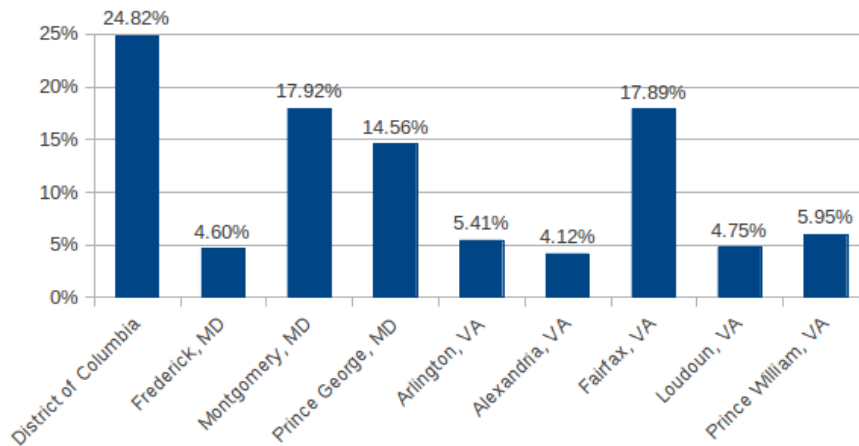


Figure 3.1: Percent of Low Income Workers by Jurisdiction out of Total Number of All Low Income Workers in the Washington D.C. Metropolitan Region.

3.1.3 Low Income Employment Analysis by Occupation and Sector

The occupation codes in the data set are identified using the 2000 Standard Occupation Classification (SOC) System. However, there is a large portion of N.A. (not applicable) responses (21%). There are 26 designations for occupation industry within the SOC system. Table 3.2 shows a breakdown of the jobs within the Washington D.C. Metropolitan Region, the percentage of that specific occupation that are employed by low income workers, the percentage of low income workers for each occupation as a fraction of the total number of low income workers, and the categorization of the occupation into one of the four sectors identified by MWCOC.

20.7% of workers put "N.A." as their job occupation, of which 7.1% reside in low income households, but all this accounts for 22.3% of all low income household workers in the region. Managers (11.3%) are the majority of workers in the region,

of which less than 2% are in low income households. The top five largest occupations employing low income household workers are: office jobs (10.3%), sales (8.9%), the food industry (8.0%), the cleaning industry (7.5%), and the construction industry (7.4%). Within each occupation industry, the top five occupations with the largest percentage of workers in low income households are: agriculture (24.7%), the cleaning industry (19.9%), the food industry (18.8%), personal care and services (16.7%), and healthcare support (14.6%).

Figure 3.2 shows the percentage rate breakdown of all low income workers into the four sectors. The lowest percentage of low income workers are office workers. A majority of low income workers are found working other and industrial jobs.

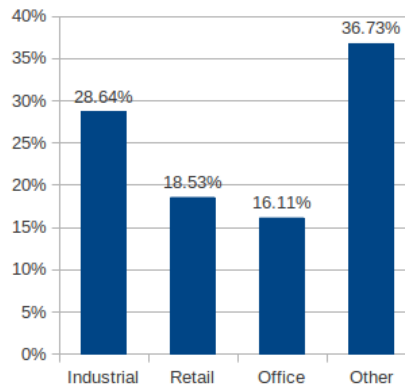


Figure 3.2: Percent of Low Income Workers by Sector out of Total Number of All Low Income Workers in the Washington D.C. Metropolitan Region.

Table 3.2: Percentage of Low Income Workers for the Washington D.C. Metropolitan Region by Occupation.

Occupation	Percent of Total Workers	Percent of Low Income Workers in each Occupation	Percent of Total Low Income Workers	Round 8a Cooperative Forecast Employment Data Sector
Manager	11.34%	1.86%	3.23%	Office
Business	3.36%	1.6%	0.82%	Office
Finance	2.95%	1.84%	0.83%	Office
Communication	5.83%	1.37%	1.22%	Retail
Engineering	2.00%	0.99%	0.30%	Other
Science	1.79%	2.21%	0.60%	Other
Community and Social Services	1.14%	5.58%	0.97%	Retail
Legal Services	2.66%	2.42%	0.98%	Office
Education	4.45%	5.03%	3.42%	Other
Entertainment Industry	2.50%	3.75%	1.43%	Industrial
Medicine (Doctors and Nurses)	3.31%	3.51%	1.77%	Other
Healthcare Support	1.10%	14.61%	2.44%	Other
Protective Services	2.25%	5.48%	1.88%	Retail
Food Industry	2.79%	18.77%	7.98%	Industrial
Cleaning Industry	2.49%	19.86%	7.54%	Industrial
Personal Care and Service	2.20%	16.66%	5.60%	Retail
Sales	6.54%	8.88%	8.86%	Retail
Office	10.18%	6.60%	10.25%	Office
Agriculture	0.07%	24.69%	0.28%	Industrial
Construction	3.80%	12.69%	7.36%	Industrial
Extraction	0.01%	7.52%	0.02%	Industrial
Repair	1.88%	6.76%	1.94%	Industrial
Production	1.55%	8.79%	2.09%	Industrial
Transportation	2.55%	14.14%	5.50%	Other
Military	0.55%	4.88%	0.41%	Other
Not Applicable	20.69%	7.06%	22.28%	Other
Total	100%	6.56%	100%	

Source: American Community Survey 2006-2010, 5-year Estimates

3.2 Low Income Employment Forecast Analysis

A statistical and spatial of the Washington D.C. Metropolitan Region is performed to examine the low income job location, forecast, and growth using the

American Community Survey 2006-2010, 5-year estimates along with Round 8a Cooperative Forecast Data from the Metropolitan Washington Council of Governments.

3.2.1 Low Income Employment Forecast Data

The data analysis from job availability is used in conjunction with the Round 8a Cooperative Forecast Employment Data, a long-range economic and demographic forecast. The Round 8a Cooperative Forecast Employment Data are aggregated at the Transportation Analysis Zone (TAZ) level, which amounts to 3,675 zones. This encompasses the Washington D.C. Metropolitan Region of interest (2,950 zones) and then some. Both a regional top-down and local bottom-up approach is employed for the Round 8a Cooperative Forecast Employment Data. A regional model based on national economic and demographic factors is used to forecast. Employment is forecasted with 2005 being the base year and forecasts for the years 2010 to 2040 and every five years in between for every TAZ within the region.

The dataset also includes: land area (in acres and square miles), number of households, population, and group quarter population. Given the employment and land area, employment density can be calculated for each TAZ and GIS maps can be created for a visual depiction of job availability and large concentration of jobs employed by low income peoples.

Employment data are separated into four occupational sectors: industrial, retail, office, and other. The poverty analysis from above is used to forecast and

identify locations of low income jobs within the region. The occupation codes designated by the SOC System are divided into the four categories: industrial, retail, office, and other as shown in Table 3.2. In the Round 8a Cooperative Forecast Employment Data set, there are 3,780,290 jobs in the Washington D.C. Metropolitan Region for the 2005 base year. Of which, 14% are categorized as industrial jobs, 18% retail, 47% office, and 21% other.

3.2.2 Low Income Employment Forecast by Jurisdiction

A statistical and spatial of the Washington D.C. Metropolitan Region is performed to examine the low income job location, forecast, and growth within each jurisdiction using the American Community Survey 2006-2010, 5-year estimates along with Round 8a Cooperative Forecast Data from the Metropolitan Washington Council of Governments.

3.2.2.1 Employment Forecast by Jurisdiction Methodology

Figure 3.3 shows the percent of low income workers *within* each jurisdiction. This means that 6.35% of all employed individuals in the District of Columbia are low income individuals. These percentages of low income workers from the ACS were used to forecast and identify concentrations of low income workers in the region from the Round 8a Cooperative Forecast Employment Data. Because the ACS data are aggregated at the county (jurisdiction) level, it was assumed that the percentage of low income workers within the jurisdiction is uniformly distributed across all TAZs

for that jurisdiction.

For example, it is assumed for all TAZs within the District of Columbia, 6.35% of workers in all of these TAZs are low income workers. This is a very general assumption for each jurisdiction within the region; therefore, it should be recognized that certain TAZs will have larger concentrations of low income workers, but without additional information on individual TAZs it would not be possible to distinguish between them.

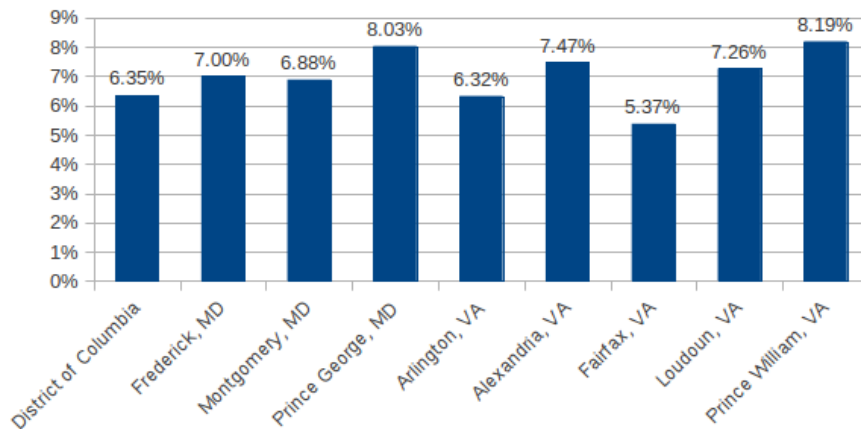


Figure 3.3: Percent of Low Income Workers *within* Each Jurisdiction in the Washington D.C. Metropolitan Region.

3.2.2.2 Low Income Employment Forecast by Jurisdiction Results

Table 3.3 is the result of the applied assumption that low income workers are uniformly distributed across all TAZs within each jurisdiction. The growth of low income jobs range from 22% in Arlington (with one of the highest employment densities within the region) to 107% in Loudoun County (with one of the lowest

employment densities within the region).

Table 3.3: Low Income Employment Forecast by Jurisdiction for the Washington D.C. Metropolitan Region.

Jurisdiction	2005	2010	2015	2020	2025	2030	2035	2040	Percent Change
Total	171,934	180,011	190,569	203,991	214,736	225,300	235,146	243,848	41.83%
District of Columbia	41,508	43,434	45,815	48,561	50,145	52,403	54,677	56,202	35.40%
Frederick, MD	7,776	9,058	9,639	10,072	10,377	10,611	10,846	11,097	42.71%
Montgomery, MD	29,178	29,808	31,418	33,665	35,836	38,164	39,832	40,909	40.20%
Prince George, MD	29,302	30,132	31,065	32,100	33,303	34,766	36,597	38,989	33.06%
Arlington, VA	9,430	9,719	9,873	10,505	11,002	11,176	11,434	11,483	21.77%
Alexandria, VA	7,128	7,284	7,670	7,950	8,421	8,699	9,156	9,442	32.46%
Fairfax, VA	27,564	29,113	30,724	32,973	34,466	35,697	36,687	37,626	36.50%
Loudoun, VA	9,077	10,206	11,723	14,130	15,912	17,169	17,980	18,786	106.96%
Prince William, VA	10,971	11,257	12,642	14,035	15,274	16,615	17,937	19,314	76.05%

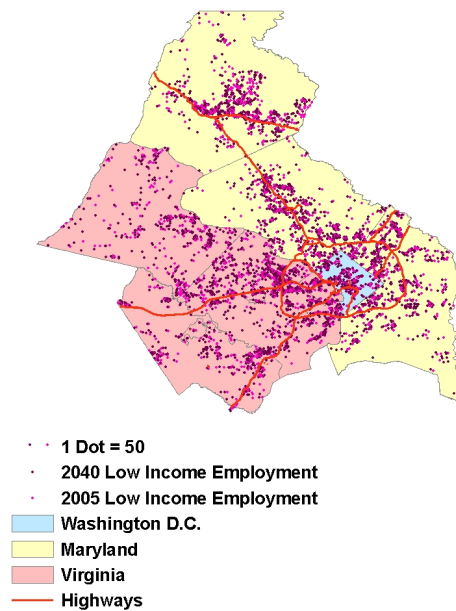


Figure 3.4: 2005 (Base Year) and 2040 (Forecasted Year) Low Income Employment Dot Density.

The location of this low income employment growth is in Figure 3.4, where the 2005 base year data and the 2040 forecasted year data is plotted. As it can be

seen, there are larger clusters of low income employment along the major highway corridors. As it can be seen, the job growth (Frederick County, Loudoun County, and Prince William's County) does not correspond well with the current location of low income households (District of Columbia and Prince George's County).

3.2.2.3 Low Income Employment Forecast by Sector Methodology

Figure 3.5 shows the percent of low income workers *within* each sector. This means that 12.43% of all employed individuals in the region are working in the industrial sector. These percentages of low income workers from the ACS along with the Round 8a Cooperative Forecast Employment Data were used to forecast the sector in which low income workers are employed. Because the ACS data are aggregated at the county (jurisdiction) level, it was assumed that the percentage of low income workers within the sector is uniformly distributed across all TAZs.

For example, it is assumed for all TAZs within the entire Washington D.C. Metropolitan Region, 12.43% of all industrial workers reside in low income households, 6.76% of all retail workers reside in low income households, 3.46% of all office workers reside in low income households, and 6.61% of all other workers reside in low income households. This is a very general assumption for the entire region; therefore this percentage of low income workers by sector is calculated for each jurisdiction. It should be recognized that certain TAZs will have larger concentrations of jobs of a particular sector, but without additional information on individual TAZs it would not be possible to distinguish between them.

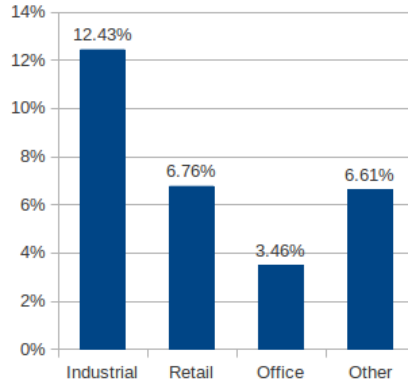


Figure 3.5: Percent of Low Income Workers *within* Each Sector in the Washington D.C. Metropolitan Region.

3.2.2.4 Low Income Employment Forecast by Sector Results

The growth of low income jobs for each sector for the Washington D.C. Metropolitan Region is also shown in Table 3.4. Low income office jobs are expected to have the largest job growth at 53.0% and other low income jobs are expected to have the smallest job growth at 30.5% which corresponds to the increase share of low income office jobs ($\uparrow 2.4\%$) and the decrease in other low income jobs ($\downarrow 1.9\%$). However office jobs within the region have the lowest percentage of low income workers (ref. Figure 3.5). Therefore a shift is seen to have more low income office jobs than other low income jobs. The largest number of low income workers is found in office jobs, in which growth is forecasted to be 53%.

The low income employment growth is then separated by sectors to visualize the location of low income employment for the industrial, retail, office, and other sectors. Figure 3.6(a) shows low income employment for the industrial sector clus-

Table 3.4: Low Income Employment Forecast by Sector for the Washington D.C. Metropolitan Region.

	2005	2010	2015	2020	2025	2030	2035	2040	Percent Change
Employment Forecast	2,925,554	3,075,139	3,280,147	3,546,854	3,762,996	3,948,338	4,119,340	4,275,070	46.13%
Industrial	324,086	337,693	352,357	376,800	393,823	418,018	439,913	452,189	39.53%
Retail	530,519	564,064	594,505	636,686	668,951	699,765	729,570	758,954	43.06%
Office	1,500,577	1,576,613	1,703,094	1,876,953	2,021,355	2,130,357	2,229,306	2,319,928	54.60%
Other	570,372	596,769	630,191	656,415	678,867	700,198	720,551	743,999	30.44%
Low Income Employment	171,934	180,011	190,569	203,991	214,736	225,300	235,146	243,848	41.83%
Industrial	41,270	42,885	44,701	47,699	49,796	52,815	55,572	57,096	38.35%
Retail	38,456	40,747	42,933	45,826	48,051	50,275	52,469	54,738	42.34%
Office	51,952	54,389	58,567	64,223	69,063	72,846	76,297	79,493	53.01%
Other	40,256	41,990	44,368	46,243	47,826	49,364	50,808	52,521	30.47%

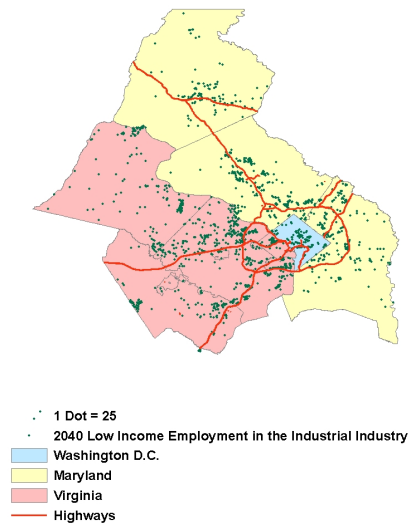
tering around major highway corridors (e.g., I-95, I-270, and I-66). There is a larger cluster of low income industrial employment around the Reston, Virginia area.

As seen in Figure 3.6(b), the retail sector employs a lot of low income individuals in a more dispersed manner across the region. This is expected due to the nature of retail positions. There is clustering around major highway corridors (e.g., I-95, I-270, I-66, Rt. 70, etc.) as many retail businesses would operate. Retail businesses are more evenly distributed in the Virginia portion of the region which would be expected for the suburban lifestyles seen in Fairfax, Loudoun, and Prince Williams County, Virginia.

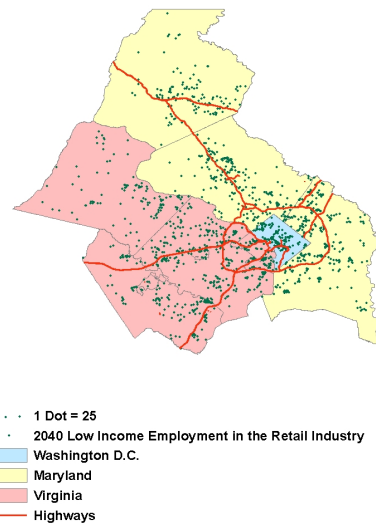
The largest percentage of low income jobs are office jobs when not taking into account those employed in the "other" sector. This is apparent in Figure 3.6(c). The clustering of low income office jobs is also seen around major corridors (i.e., I-95, I-270, Rt. 70) and much more densely packed within the Capital Beltway (i.e.,

I-495).

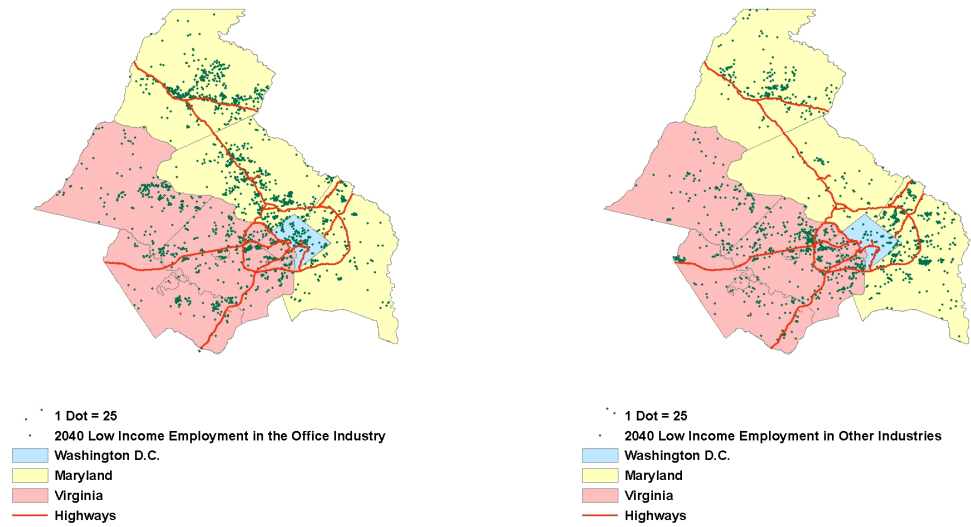
The distribution of low income jobs in the "other" sector is shown in Figure 3.6(d). The largest percentage of low income jobs can be found in jobs outside the: industrial, retail, and office sectors. This includes a wide range of occupations, consequently, trends for these low income jobs can only be compared to the other three sectors. The distribution of low income jobs in the "other" sector is uniform throughout the region except in Montgomery County where a majority of low income jobs are in the industrial, retail, and office sectors.



(a) Industrial Sector.



(b) Retail Sector.



(c) Office sector.

(d) Other Sector.

Figure 3.6: Low Income Employment by Sector Forecasted for 2040.

3.2.3 Low Income Employment Forecast Major Trends

A large percentage of low income workers are found to be currently employed in: the District of Columbia, Montgomery County, Prince George’s County, Fairfax County. From the forecast of low income employment, it can be seen that a majority of employment growth is seen in the suburban areas and counties surrounding Washington D.C. These can be seen in: Loudoun County, Prince Williams County, and Frederick County. This employment growth is also spatially clustered around major corridors like Interstate-270 and Interstate-66. Therefore these areas should be places of focus for increasing accessibility to these regions. To fill these new positions, low income individuals will have to spread out even more. These job growth locations do not coincide with where low income workers currently live; therefore,

low income individuals may need to travel even further to obtain these jobs, making this highly problematic. This alludes to the possibility of a spatial mismatch between the two.

3.2.3.1 Median Household Income and Value

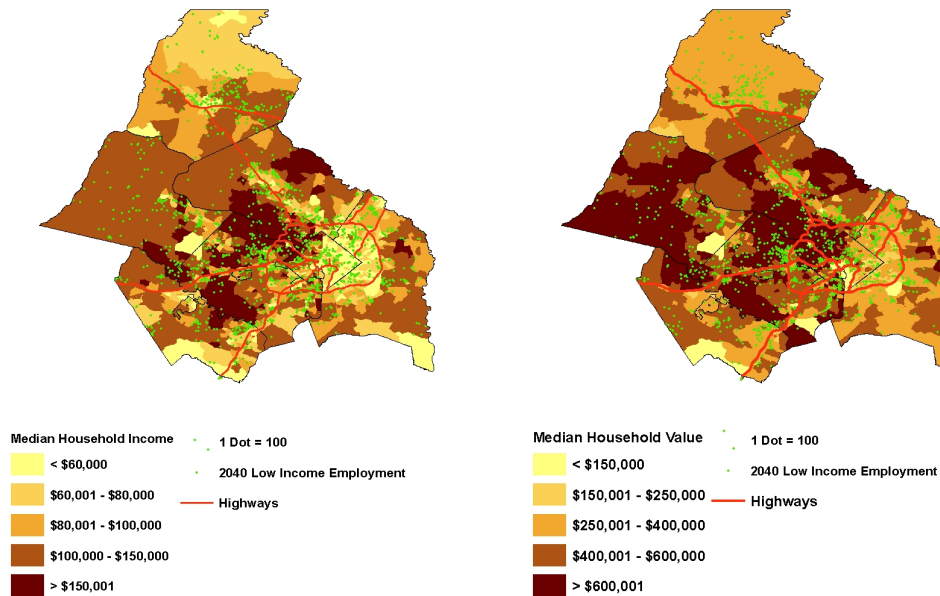
To better understand if there is a spatial mismatch occurring, the median household income and value taken from the ACS was examined at the U.S. Census tract level. Figure 3.7(a) shows the superposition of the low income household and low income employment growth.

There are several TAZs where the median household income is identified as greater than \$250,000. Lower income areas are seen in the eastern region of Washington D.C., portions of Prince Georges County, northern portions of Frederick County, and portions of Northern Virginia (parts of Arlington, Alexandria, and Fairfax County). The more affluent areas are seen in Montgomery, portions of Fairfax County, and overall Loudoun County. There are also several TAZs where the median household value is identified as greater than \$1,000,000. As expected, household income and household value are highly correlated such that the more affluent neighborhoods correspond to residing in more expensive housing and lower income area residents residing in less costly homes.

In the eastern portion of the region including: eastern Washington D.C. and Prince Georges County there is a large region of low income households with some dispersed low income employment. This is also seen where there is major corridors

such as Interstate-270 thorough Montgomery County and Frederick County and along Interstate-95 through Prince Williams County. However, there are large areas of high income households right outside the immediate vicinity of these major interstates/highways. Therefore these low income workers either live in the immediate vicinity of the corridor or major commuting is required to reach these employment centers.

Also the growth of low income employment in Loudoun County is expected to be quite high, however, the overall median household income level and the median household value (ref. Figure 3.7(b)) is quite high. Therefore low income workers in the area would have to perform a reverse commute into the suburbs of Loudoun County.



(a) Median Household Income.

(b) Median Household Value.

Figure 3.7: Spatial Analysis of Median Household Income and Value and Low Income Employment.

3.3 Low Income Employment Analysis and Forecast Conclusions

Growth of low income jobs can be seen along major corridors and counties surrounding Washington D.C. With already high employment density, the District of Columbia is expected to have limited job growth. Hence, the most growth is seen within the surrounding counties outside the District of Columbia. Growth is seen along the major interstate/highway corridors, I-270, I-66, and I-95 within Prince George's, Prince William's, and Fairfax County. However, there is also a dispersal of jobs seen throughout the county. This is especially apparent in Loudoun County where low income job growth is dispersed throughout the county. Therefore, low income employment are increasingly being located within the surrounding counties, moving further away from the Washington D.C. business district. But looking at the higher median household value of these areas (as compared to the household value in other counties), it may not be feasible to work and reside in other than Prince George's County and parts of Washington D.C.

The overall low income job growth is lower than the total employment growth for the region as a whole. There is a higher distribution of low income jobs within the industrial, retail, and other jobs sector as compared to the employment growth distribution of the entire region. More than 50% of the all jobs within the region are office jobs. However, out of the total low income jobs for the entire region, only 33% of them are office jobs. Therefore a majority of the forecasted office job growth will not be low income office jobs.

Future studies should attempt to minimize the assumption used to forecast

low income job growth with additional TAZ information. This will result in a more realistic forecast because currently, is impossible to distinguish those individual TAZs with higher low income households when assuming a uniform low income employment distribution across a big area such as the PUMA.

Chapter 4

National Household Travel Survey Trip Analysis

4.1 Trip Analysis

4.1.1 Introduction

As mentioned in Chapter 1, research has shown that the daily travel patterns of low income individuals are quite different from higher income level individuals. The travel time and distance is analyzed differentiated by mode, work day, employment status, number of household vehicles, gender, and destination purpose. Looking at who makes different types of trips, on different modes with different employment status gives a better understanding of the travel patterns of low income individuals. Understanding these travel patterns can give a better sense of the transportation difficulties that pertain to low income individuals and households.

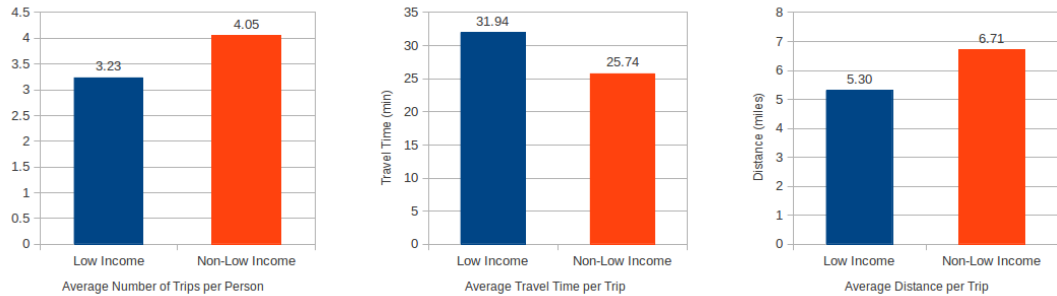
4.1.2 Data

The 2007/2008 National Household Travel Survey (NHTS) data set (i.e., person, household, and trip data files) was used to analyze the trips made by low income individuals within the Washington D.C. Metropolitan Region. The NHTS individuals were filtered to just those living within the Washington D.C. Metropolitan region. Individuals in low income households were identified as those households

whose household income falls below 1.5 times the poverty level as identified in Table 2.1 in Chapter 2.

4.1.3 Trip Analysis Results and Discussion

Figure 4.1 shows the average number of trips per low income and non-low income individuals and the average travel time and distance per trip for all trip purposes and modes. Low income individuals spend 25% more time traveling during each trip but travel 21% fewer miles than higher income level individuals. This extra time spent traveling adds up over multiple trips contributing to substantial amounts of total daily travel time. Therefore it is especially important for low income individuals to have fast, convenient, and reliable transportation modes.



(a) Average Number of Trips. (b) Average Travel Time per Trip. (c) Average Travel Distance per Trip.

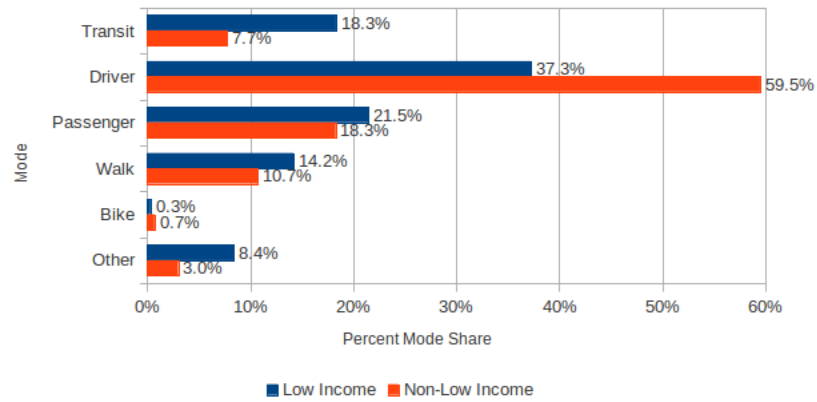
Figure 4.1: Trip Analysis for *All* Trip Purposes and Modes.

Source: 2007/2008 National Household Travel Survey

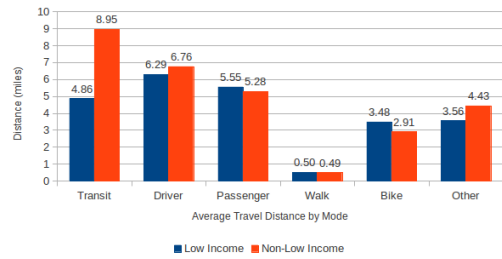
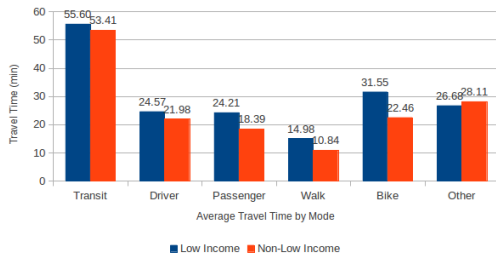
4.1.3.1 Trip Analysis by Mode

The transportation mode taken by low income individuals can explain the longer travel times (ref. Figure 4.2(a)). Low income individuals use transit twice as much as higher income level individuals. There are also 37% more drivers for trips made by non-low income individuals. More trips made by carpooling, walking, and other transportation mode trips for low income individuals as well.

The average travel time and distance for these trips (ref. Figure 4.2(b) and 4.2(c)) explains the increased travel time per trip for low income individuals. For almost every mode, low income individuals spend more time per trip traveling shorter distances than non-low income individuals. Though the transit travel times are comparable, low income individuals travel nearly 46% less far on transit. This alludes to the idea that rail transit attracts more discretionary due to its cost (as mentioned in Chapter 1). Hence, higher income level individuals can afford the pricier rail transit that have longer travel distances with comparable travel times as other public transit modes.



(a) Percent Mode Share.



(b) Average Travel Time by Mode per Trip. (c) Average Travel Distance by Mode per Trip.

Figure 4.2: Trip Analysis by Mode.

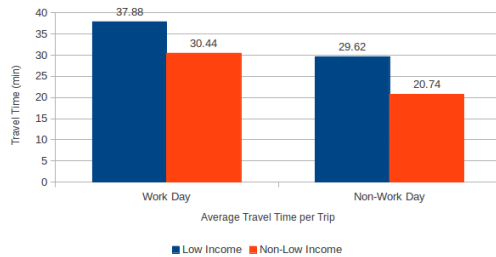
Source: 2007/2008 National Household Travel Survey

4.1.3.2 Trip Analysis by Work Day

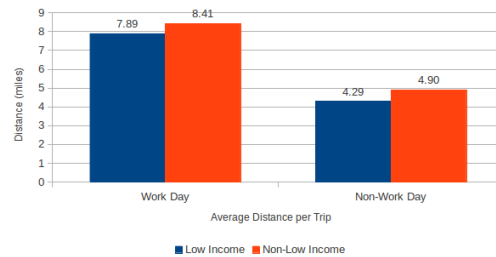
It is expected that the travel pattern for work days and non-work days would be different (ref. Figure 4.3). However, it was unexpected to see that there are more trips made during non-work days for both low income individuals and non-low income individuals. The overall travel time and distance is more for work day trips. Again it is seen that low income individuals have longer travel times for shorter travel distances. This is especially prominent for non-work day trips.



(a) Average Number of Trips by Work Day.



(b) Average Travel Time by Work Day.



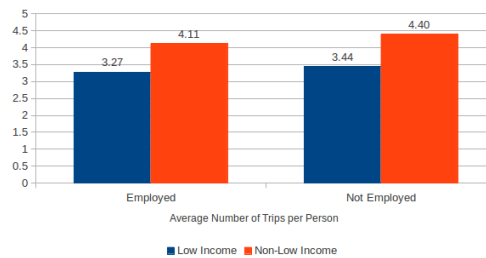
(c) Average Travel Distance by Work Day.

Figure 4.3: Trip Analysis by Work Day.

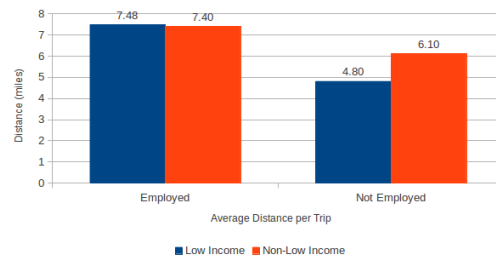
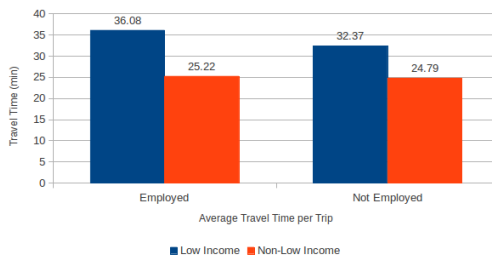
Source: 2007/2008 National Household Travel Survey

4.1.3.3 Trip Analysis by Employment Status

Employment is separated from work day such that Figure 4.4(a) represents trips made by individuals who identified as either employed or unemployed. Again it is apparent the differences in the number of trips, average travel time, and average travel distance between low income and non-low income individuals (ref. Figure 4.4). Not employed individuals travel shorter distances overall compared to employed individuals.



(a) Average Number of Trips by Employment Status.



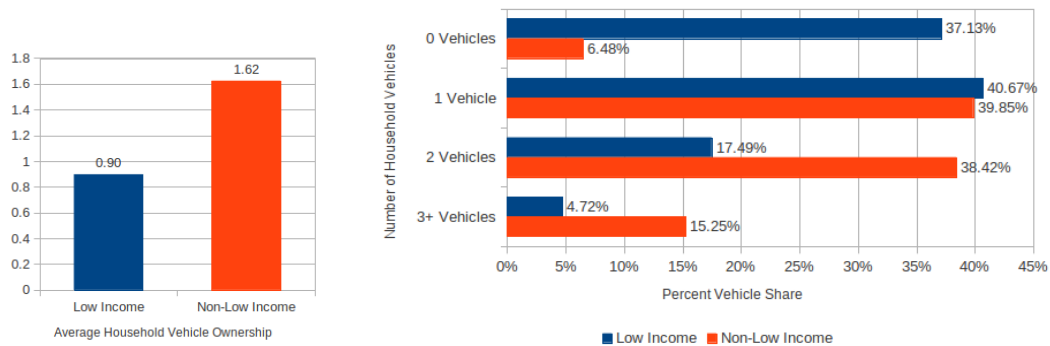
(b) Average Travel Time by Employment Status (c) Average Travel Distance by Employment Status.

Figure 4.4: Trip Analysis by Employment Status.

Source: 2007/2008 National Household Travel Survey

4.1.3.4 Trip Analysis by Number of Household Vehicles

The average number of household vehicles and the distribution of the number of household vehicles is shown in Figure 4.5. Low income households are six times more likely to not own a vehicle with an average car ownership rate of less than one. 78% of low income households own either one or no vehicle. 78% of higher income households own either one or two vehicles resulting in a vehicle ownership rate of 1.62.



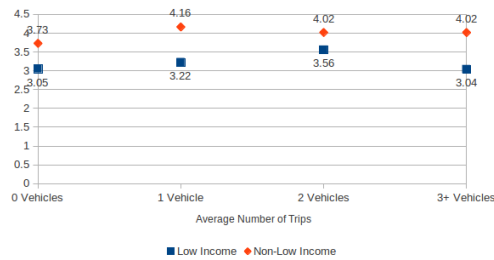
(a) Average Household Vehicle Ownership. (b) Distribution of Number of Household Vehicles.

Figure 4.5: Vehicle Ownership.

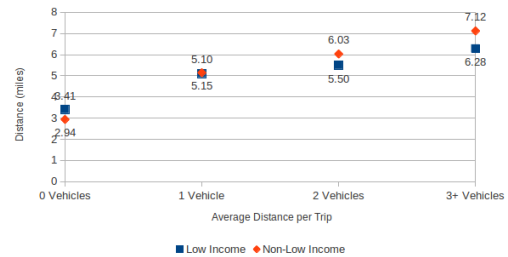
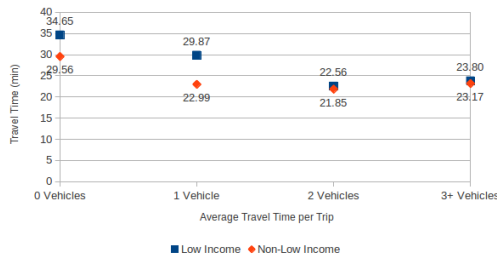
Source: 2007/2008 National Household Travel Survey

The average number of trips given the number of household vehicles is shown in Figure 4.6(a). The travel time per trip for low income individuals for all numbers of household vehicles is lower than for higher income individuals. For households with no vehicles, trip travel distance is lower for higher income individuals, therefore they are living closer to work, shopping, school, etc, enabling them to make shorter trips. For households with one or more vehicles, trip travel distance increases for low and

non-low income individuals. Therefore with the attainment of at least one vehicle, individuals are willing to travel further to work, shopping, school, etc. However, overall, low income individuals still make less number of trips even for households with equivalent number of vehicles (ref. Figure 4.6(c)).



(a) Average Number of Trips by Number of Household Vehicles.



(b) Average Travel Time by Number of Household Vehicles. (c) Average Travel Distance by Number of Household Vehicles.

Figure 4.6: Trip Analysis by Number of Household Vehicles.

Source: 2007/2008 National Household Travel Survey

4.1.3.5 Trip Analysis by Gender

The average number of trips made by males and females (separated by low income and non-low income) are shown in Figure 4.7(a). There isn't much difference in the number of trips made and the average travel time and distance between males

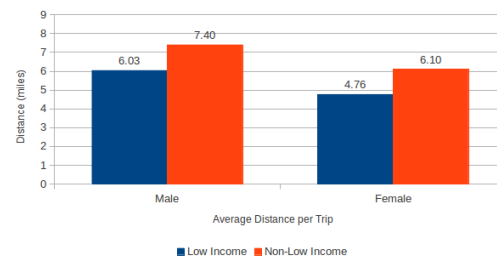
and females. However, there is a slight trend for females to make more trips, but take less time traveling shorter distances (ref. Figure 4.7(b) and 4.7(c)). This may be explained with household chores being undertaken by females more so than males. Again it is apparent the differences in the number of trips, average travel time, and average travel distance between low income and non-low income individuals.



(a) Average Number of Trips by Gender.



(b) Average Travel Time by Gender.



(c) Average Travel Distance by Gender.

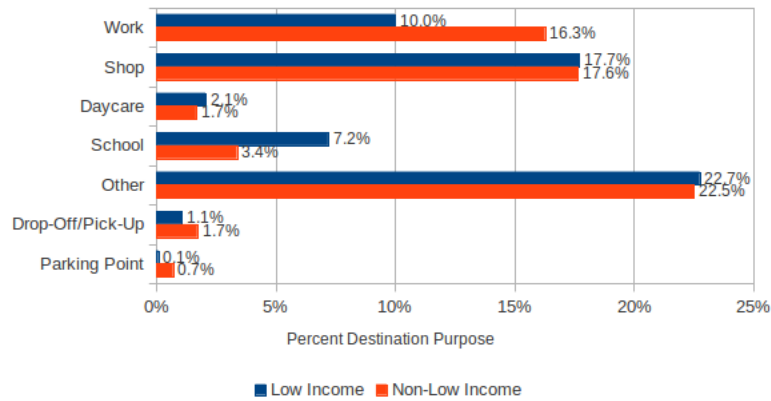
Figure 4.7: Trip Analysis by Gender.

Source: 2007/2008 National Household Travel Survey

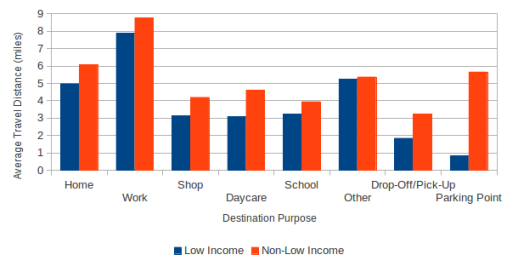
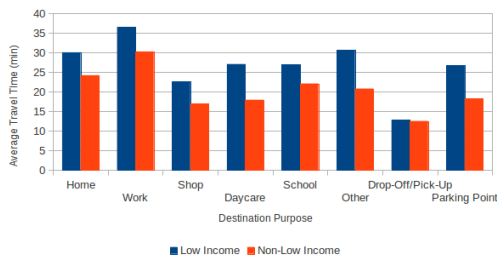
4.1.3.6 Trip Analysis by Origin and Destination Purpose

The origin-destination purpose is shown in Figure 4.8(a). The travel time and distance per trip for each origin-destination purpose is shown in Figure 4.8(b) and 4.8(c). Note that only select origin-destination purposes are shown. Intercity rail,

intercity bus, airport, gas station, and external origin-destination purposes were not included. As expected there are less trips made to and from work for low income individuals as compared to higher income individuals. They make comparable number of shopping trips. Low income individuals only make slightly more trips to daycare than non-low income individuals and make nearly twice as many school trips than non-low income individuals. When comparing travel time and distance, low income individuals consistently spend more time traveling to these destinations while traveling shorter distances.



(a) Destination Purpose.



(b) Average Travel Time by Destination Purpose.

(c) Average Travel Distance by Destination Purpose.

Figure 4.8: Trip Analysis by Origin and Destination Purpose.

Source: 2007/2008 National Household Travel Survey

4.2 Tour Analysis

4.2.1 Introduction

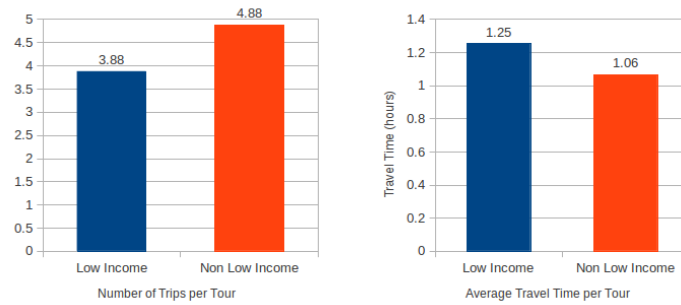
As mentioned in Chapter 1, research has shown that the daily travel patterns of low income individuals are quite different from higher income level individuals. Looking at tours gives a better understanding of the travel patterns of low income individuals and how efficiently they chain trips together. Understanding these travel patterns can give a better sense of the transportation difficulties that pertain to low income individuals and households.

4.2.2 Data and Methodology

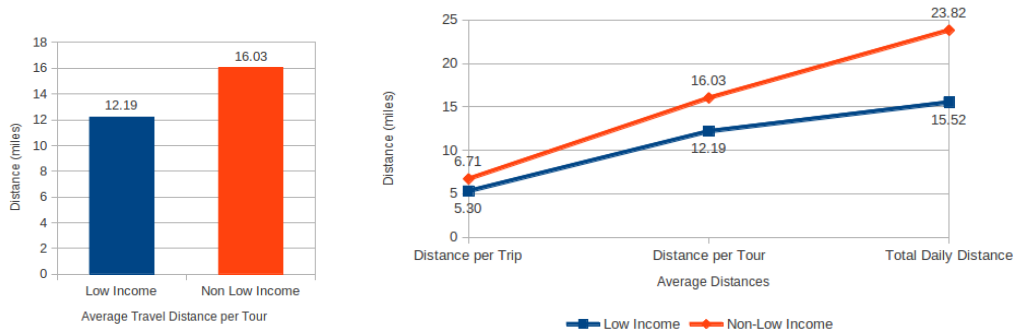
Again, the 2007/2008 National Household Travel Survey (NHTS) data set (i.e., person, household, and trip files) was used to analyze the trips made by low income individuals within the Washington D.C. Metropolitan Region. The NHTS individuals were filtered to just those living within the Washington D.C. Metropolitan region. Individuals in low income households were identified as those households whose household income falls below 1.5 times the poverty level as identified in Table 2.1 in Chapter 2. The trips reported in the travel survey were chained to create home-based tours. Therefore for each tour, the origin and destination is home and all trips in between are chained together for that particular tour.

4.2.3 Tour Analysis Results and Discussion

The number of trips per tour are shown in Figure 4.9(a). As expected, low income individuals make fewer trips in each tour, therefore they are chaining fewer trips together than non-low income individuals. The average travel time and distance during a tour is also shown in Figures 4.9(b) and 4.9(c). With more trips chained together, higher income individuals travel further distances per tour. Higher income individuals travel further per trip and per tour, resulting in an overall larger daily travel distance than low income individuals (ref. Figure 4.9(d)).



(a) Average Number of Trips per Tour. (b) Average Travel Time within a Tour.



(c) Average Distance Traveled within a Tour. (d) Daily Distance Traveled.

Figure 4.9: Tour, Trip Chaining Analysis.

4.2.3.1 Work Statistics

The percentage of low income and higher income individuals working from zero to four jobs are shown in Figure 4.10. There is a clear distinction in the number of jobs held by low income and higher income individuals. There are nearly 30% more low income individuals with no job as compared to higher income individuals. Also, there is 25% more higher income individuals with just one job as compared to low income individuals.

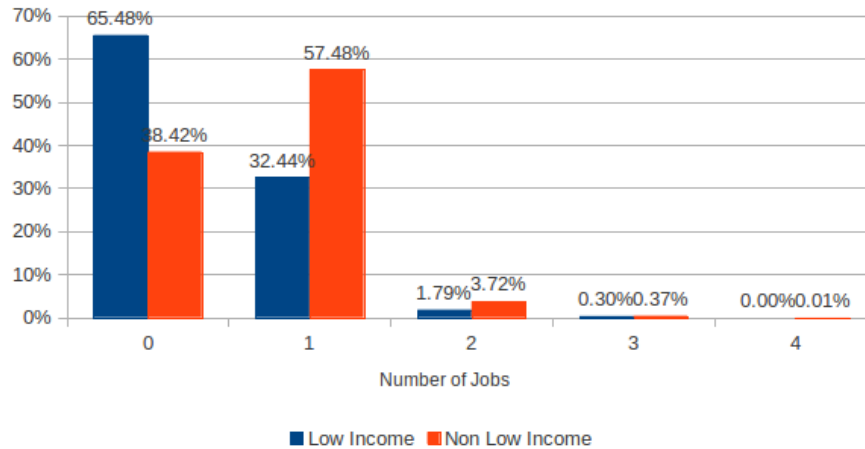
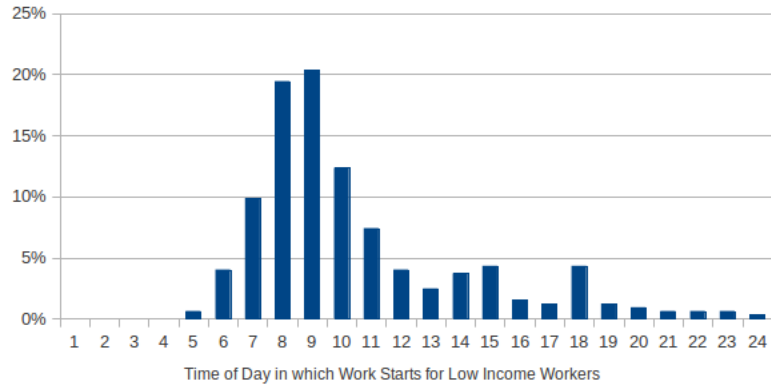
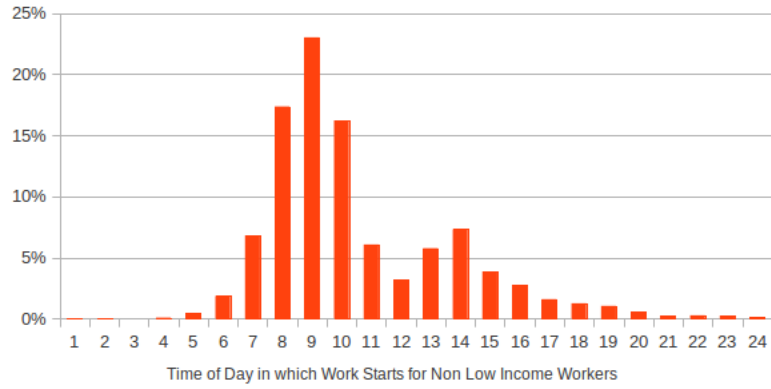


Figure 4.10: Percentage Share for the Number of Jobs.

The time of day in which individuals start work is shown in Figure 4.11. For non low income individuals (ref. Figure 4.11(b)), there is a large trend for workers to go to work by 9 or 10 am and come back to work after lunch around 2 pm, with very few individuals arriving at work after 5 pm. For low income individuals (ref. Figure 4.11(a)), there are more workers arriving before 8 am and after 6 pm as compared to higher income individuals.



(a) Time of Day in which *Low Income Individuals* Start Work.



(b) Time of Day in which *Non-Low Income Individuals* Start Work.

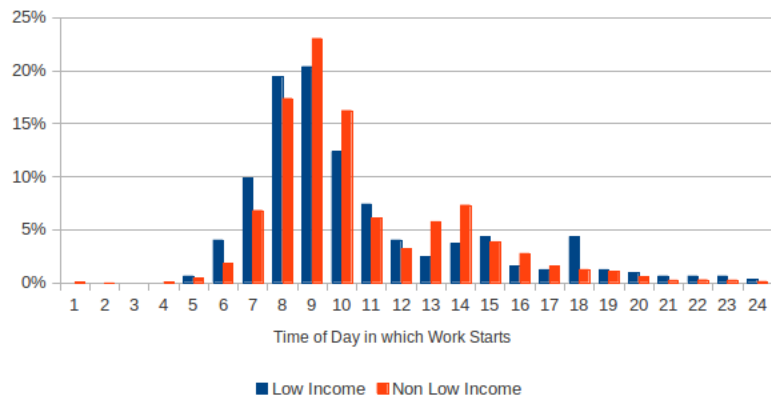


Figure 4.11: Time of Day in which Individuals Start Work.

4.3 National Household Travel Survey Trip and Tour Analysis

Conclusions

There is a significant difference between the number of trips and tours made by those living in low income households and those living in higher income households. This is especially emphasized when looking at the total daily travel distance traveled. Low income individuals are consistently traveling shorter distances for their trips and tours. However, low income individuals are also consistently traveling for longer and going less far. This can be explained by the higher mode share percentages for slower forms of transportation (i.e., public transit, walking, and biking). The biggest difference is seen in public transit usage, where low income individuals make a significant percentage of trips by public transit, traveling shorter distances, and for longer travel times. This is supportive of the idea introduced in Chapter 1 that higher income individuals are discretionary riders being able to afford the pricier rail transit services that have longer travel distances with comparable travel times as the slower bus transit system.

The average number of household vehicles is less than one for low income individuals. This is apparent when 35% of households have no vehicles while this accounts for only 6.5% of higher income individuals. For both income levels, an increase from zero household vehicles to one household vehicles increases the average number of trips, but plateaus for higher income levels at two vehicles and above.

For the selected origin-destination purposes, it is obvious that higher income individuals go to work more often than low income individuals. Low income individ-

uals also travel to school more often. Day care, shopping, other, drop-off/pick-up, and parking point are all similar for both income levels. When comparing travel time and distance, low income individuals consistently spend more time traveling shorter distances to these destinations.

Corresponding with the low share of work trips being made, it is seen that low income individuals are not working when examining the number of jobs held. A significantly larger proportion of individuals in low income households are simply not employed. Low income workers also have more time constraints as a larger percentage of them arrive to work in the early hours between 5 and 8 am while those in higher income jobs arrive between 9 and 10 am. This can appeal to the flexibility of higher income salary jobs held by non-low income individuals. Also, it is also seen that there are larger number of low income workers starting work at 6 pm as well. Therefore, transit dependent low income workers would need a public transportation system that serves these time frames.

Higher income individuals chain more trips together, making on average more trips per tour than low income individuals. However, low income individuals are still traveling longer for shorter distances for less number of trips within a tour. This supports the larger public transit mode share usage seen by low income individuals. This supports the notion of the possibility of transit dependent low income riders mentioned in Chapter 1. This dependency on inefficient, slow, and expensive public transit due to lack of an available privately owned vehicle shines light onto one of the main factors hindering job accessibility for low income individuals.

Chapter 5

Policy Analysis

5.1 Introduction

The typical recommended programs for urban regions with some level of public transit connectivity is subsidizing public transportation. Though this is widely suggested, low levels of connectivity or inefficient public transportation networks hinder the effectiveness of such programs. Therefore while this may be an easier to execute, those who qualify may not be using it to its fullest potential. Two policies, subsidizing public transportation and subsidizing vehicle operational costs, were implemented in this research to analyze its effect on accessibility and to see which program would be more efficient for increasing job accessibility. The first step is to choose an accessibility measure. The next step is to measure the accessibility of status quo. And finally, the change in accessibility can be measured when implementing these two strategies.

5.2 Accessibility Methodology

Transportation analysis typically uses logit choice models to measure consumer surplus. Changes in transportation cost and time are commonly used to evaluate a traveler's benefit. In this research, a disaggregate log-sum accessibility approach us-

ing the Maryland Statewide Transportation Model (MSTM) is used to measure the consumer surplus. This method measures the full accessibility benefits from land-use and transport policies when discrete choice travel demand models are available that already produce log-sums. It takes into account changes in both generalized transportation costs and destination utility; thus it is capable of providing accessibility from changes in distribution of activities due to transportation or land-use policies.

Log-sums are advantageous because it incorporates a degree of heterogeneity within the population. The log-sum also incorporates various factors that influence choice into a common framework. These factors include: different travel time and travel cost components, varying service quality, and individual and household attributes. More extensive introduction can be found in the textbooks on discrete choice models (e.g. [Train, 2003]).

The consumer surplus by definition is the utility that a person receives from their choice in monetary terms.

The utility of different alternatives for a decision maker is comprised of an observed and an unobserved (random) component:

$$U_{nj} = V_{nj} + \epsilon_{nj} \tag{5.1}$$

where U_{nj} is the utility that decision maker n obtains from alternative j from alternatives $j(n = 1, \dots, N; j = 1, \dots, J)$; V_{nj} is the “representative utility”; and ϵ_{nj} captures the unobservable factors that affect utility. In a standard multinomial logit (MNL) model, with ϵ_{nj} i.i.d. extreme value with standard variance, the choice

probabilities are given as:

$$P_{nj} = \frac{e^{V_{nj}}}{\sum_j e^{V_{nj}}} \quad (5.2)$$

If the unobserved component of utility is an independently identically distributed (i.i.d.) extreme value and the utility is linear in income, then the expected utility becomes the log of the denominator of a logit choice probability, divided by the marginal utility of income, plus arbitrary constants. This is often called the “log-sum” and it is the log of the denominator of this logit choice probability. It gives the expected utility for an alternative from a set of alternatives. The log-sum can also be used in policy evaluation in an expression for the consumer surplus [de Jong et al., 2007].

Decision makers would then choose the alternative that provides the greatest utility. Provided that the utility is linear in income, the consumer surplus (CS_n) can be calculated in monetary terms as:

$$CS_n = \left(\frac{1}{\alpha_n}\right) U_n = \left(\frac{1}{\alpha_n}\right) \max_j (U_{nj} \forall j) \quad (5.3)$$

where α_n is the marginal utility of income and equals dU_{nj}/dY_n , if alternative j is chosen. Dividing the consumer surplus by α_n translates the utility into monetary terms (e.g., dollars). Y_n is the income of person n and U_n is the overall utility for person n . If the model is MNL and utility is linear in income, then expected consumer surplus becomes:

$$E(CS_n) = \left(\frac{1}{\alpha_n}\right) \ln \left(\sum_{j=1}^J e^{V_{nj}} \right) + C \quad (5.4)$$

where C is an unknown constant that represents the fact that the absolute value of utility can never be measured. Aside from the division and addition of constants, the

expected consumer surplus in a standard logit model is simply the *log-sum*. Under the usual interpretation of the distribution of errors, $E(CS_n)$ is the average consumer surplus for the subpopulation of people who have the same representative utilities as person n . The total population consumer surplus can then be calculated as the weighted sum of $E(CS_n)$ over a sample of decision makers, whom have weights that reflect the number of people in the population that have the same representative utilities.

5.2.1 Maryland Statewide Transportation Model

The log-sum accessibility analysis is performed using the Maryland Statewide Transportation Model (MSTM) developed by the Maryland State Highway Administration (SHA) that allows for quick, consistent, and defensible estimates of how different patterns of future development can change key measures of transportation performance. The MSTM is a multi-layer model working at the regional, statewide, and urban level. Key input data to the MSTM includes the population and employment data by income category for each traffic zone. The highway network is based on the networks from Baltimore and Washington metropolitan planning organizations (MPOs), supplemented by the statewide network and the networks from surrounding states. The transit networks are derived from the Baltimore and Washington MPO networks which include: WMATA, the MTA system, MARC trains, and all local transit systems within the Baltimore-Washington D.C. area. The transit networks also include the incomplete Baltimore Red Line and the Montgomery

to Prince George’s County Purple Metro Line and the completed Inter County Connector in Montgomery County.

5.2.1.1 Parameters

Based on the MSTM framework, trips are divided into four time periods: AM peak, Mid-Day, PM peak, and Night shown in Table 5.1.

Table 5.1: Time of Day Periods.

Time Period	Time of Day
AM Peak Period	6:30 am to 9:30 am
Mid-Day Off-Peak Period	9:30 am to 3:30 pm
PM Peak Period	3:30 pm to 6:30 pm
Night Time Off-Peak Period	6:30 pm to 6:30 am (of the next day)

The population, households (categorized by size and five income levels), and employment (categorized into four industries) are used for trip generation. Income categories are based on the 2000 Census data shown in Table 5.2 .

Table 5.2: Income Groups (in 1999 Dollars).

	Income Group	Income Range	Median Income
1	Lower Quartile	< \$20,000	\$10,720
2	Lower-Middle Quartile	\$20,000 to \$39,999	\$29,840
3	Middle Quartile	\$40,000 to \$59,999	\$49,240
4	Upper-Middle Quartile	\$60,000 to \$99,999	\$76,350
5	Upper Quartile	> \$100,000	\$161,330

The MSTM is a four-step model. The parameters obtained from the model runs are used to calculate accessibility. The procedure is as follows:

5.2.1.2 Zone Selection

The MSTM uses the Statewide Model Zones (SMZ) system which consists of 1,607 zones covering all of Maryland and selected counties in adjacent states. To an extent, SMZs conform to census geography to best utilize census data products in model development/updates and model calibration and validation. SMZs range from 0.25 to 10 square miles. In areas where MPOs aggregate at the transportation analysis zone (TAZ) level, they are aggregated to the SMZ level. SMZs are nested within counties and conform to county boundaries. SMZs correspond to MWCOG identified TAZs or are an aggregation of MWCOG identified TAZs. Thus, the analysis at the SMZs captures geographical levels that are equivalent to aggregated MWCOG TAZs.

The Washington D.C. Metropolitan Region as identified by MWCOG was extracted from the MSTM data. Figure 5.1 shows the comparison between SMZs and TAZs in the study area with Washington D.C. magnified. The SMZs boundaries are shown in red, and are placed on top of TAZs boundaries shown in black. For the accessibility analysis, the income categories are stratified at the SMZs level. Individual and household information from the U.S. Census is aggregated at the Public Use Microdata Area (PUMA) level. SMZs are nested within and conform to these PUMAs, therefore the result from the accessibility analysis can be aggregated to the PUMA level.



Figure 5.1: SMZs (red) Comparison to TAZs (black) (Washington D.C. area magnified).

5.2.1.3 Trip Generation

The trip generation model within the MSTM generates trip productions by trip purpose. The trip distributions is based on joint distributions of households for each SMZ and trip production rates, which is cross-classified by household category. Work trips is the main focus of this accessibility analysis. The trips generated for work trips are based on trip production rates cross-classified by income and number of workers. In MSTM, the trip generation rates by household category were taken directly from the Baltimore Metropolitan Council (BCM)/Maryland Transit Administration (MTA) model but adjusted to the MSTM income categories (quartiles).

5.2.1.4 Trip Attraction

The trip attraction model within the MSTM calculates trips by SMZ based on a regression applied to SMZ socioeconomic variables for non-home trip ends. Table 5.3 indicates the variables used for home-based and non-home-based trip purposes in the MSTM trip attraction model.

Table 5.3: MSTM Home-Based and Non-Home-Based Trip Attraction Variables.

Variable	Definition	Trip Attraction Purposes						
		HB Work	HB School	HB Shop	HB Other	NHB JTW	NHB JAW	NHB OBO
Maintained Variables								
HH	Households			X	X		X	
WORKERS	Workers							
RE	Retail			X	X	X	X	X
OFF	Office Employment						X	
IND	Industrial Employment							
OTH	Other Employment				X		X	
ENROLL	School		X					
Derived Variables								
NRE	Non-Retail Employment	X					X	
TE	Total Employment	X						
CBDEMP	Employment in CBD Zones	X					X	
CBD	1 if Zone is in CBD, else 0						X	

5.2.1.5 Trip Distribution

The trip distribution model within the MSTM uses a gravity model formulation which employs composite travel time functions by purpose, highway and transit time, as well as roadway tolls and value of time.

5.2.1.6 Mode Choice

The mode choice model within the MSTM uses a nested logit choice model, with a nesting structure shown in Figure 5.2. The top nest consists of trips made by vehicles, be it driving alone or share riding, or public transit. In the lower nest, public transit can be accessed by driving or walking. The rail alternative includes light rail (LRT) and metro. The commuter rail (CR) alternative includes AMTRAK and MARC commuter rail services.

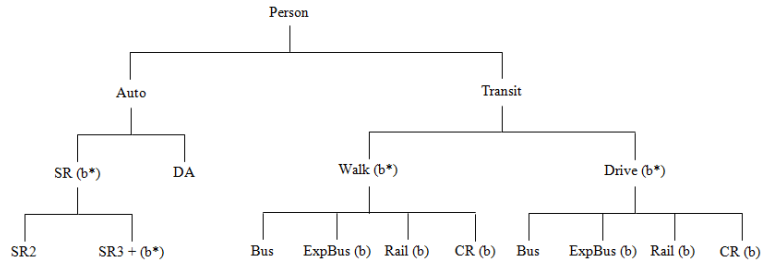


Figure 5.2: MSTM Mode Choice Model Nested Logit Structure.

Mode choice is based on generalized utility functions for auto and transit travel. Separate utilities were developed for peak and off-peak travel times. Variables in auto utilities include: driving time and cost, terminal time and parking costs at the attraction end, and tolls. Variables in transit utilities include: walking and drive-access times, initial wait times, in-vehicle travel time, and transfer time. The portion of each zone within walking distances of transit stops and stations were determined using GIS techniques. Table 5.4 list the variables that are included in the utility expression for each alternative. Table 5.5 shows the nested logit coefficients for the nests and Table 5.6 shows the coefficients for the variables found in the utility functions.

Table 5.4: Variables Included in Utility Function Based on Travel Mode Accessed by Walking and Driving.

Variable	Mode								
	wBus	weBus	wRail	wcRail	DA/SR	dBus	deBus	dRail	dcRail
In-Vehicle Time	X	X	X	X	X	X	X	X	X
Terminal Time					X				
Auto Operating Costs					X				
Auto Tolls					X				
Auto Parking Cost					X				
Walk Time	X	X	X	X		X	X	X	X
Initial Wait Time (under 7.5 min)	X	X	X	X		X	X	X	X
Initial Wait Time (over 7.5 min)	X	X	X	X		X	X	X	X
Transfer Time	X	X	X	X		X	X	X	X
Number of Transfers	X	X	X	X		X	X	X	X
Transit Fare	X	X	X	X		X	X	X	X
Drive Access Time						X	X	X	X
Attraction Zone Area Type Bias			X	X		X	X	X	X

Table 5.6: MSTM Mode Choice Utility Coefficients.

Table 5.5: MSTM Nesting Coefficients.

Nest	Value
Walk Transit Route (Bus, Rail, MARC)	0.30
Drive Transit Route (Bus, Rail, MARC)	0.30
Transit Access (Walk vs. Drive)	0.65
Share Ride Occupancy (2 vs. 3+)	0.30
Auto Mode (Drive Alone vs. Shared Ride)	0.65

Attribute	HBW, JTW
In-Vehicle Time	-0.025
Terminal Time	-0.05
Auto Operating Cost	-0.0042
Auto Parking Cost and Tolls	-0.0084
Walk Time	-0.05
Initial Wait Time (under 7.5 min)	-0.05
Initial Wait Time (over 7.5 min)	-0.025
Transfer Time	-0.05
Number of Transfers	-0.125
Transit Fare	-0.0042
Drive Access Time	-0.05

5.2.1.7 Trip Assignment

Travel demand forecasts from the MSTM was assigned to a network. Factors were applied to the respective daily trip matrices to derive peak and off-peak trip matrices for network assignment. Separate assignments are done for the AM and PM peak periods and the periods for the rest of the day were combined. Transit trips were assigned on a daily basis, work trips were assigned based on peak service characteristics, and all other trips were assigned based on off-peak service characteristics.

5.2.2 Log-Sum Measure Using the Maryland Statewide Transportation Model

5.2.2.1 Assumptions

The assumptions used in the accessibility analysis are: 1. only work trip purposes are considered (indexed by p), 2. accessibility measures is aggregated at five income levels (indexed by i), 3. the 11 mode choice alternatives as defined in Section 5.2.1.6 (mode choice index by j , mode choice *group* indexed by m) are considered, 4. and utilities are specified with a nested logit structure and parameters as defined in Section 5.2.1.6.

5.2.2.2 Log-Sum Measure by Income Group

For each origin zone z within the area, the log-sum is computed for each income group i , travel purpose p (only work trips are considered), and transportation alternatives $j \in J$ to all destinations within the study area:

$$L_{piz} = \ln \left(\sum_{j=1}^J e^{\mu_p V_{pijz}} \right) \quad (5.5)$$

where μ_p is the nesting coefficient (based on the nested logit structure) and V_{pijz} is the deterministic utility obtained from transportation mode j .

The log-sums are aggregated for work trips at five income levels. Then the log-sum is converted into travel time by time coefficient, β_p and then converted into travel cost by external values of time, VoT_{pi} . Thus, the monetary value of the accessibility of zone z for a person of income group i can be written as:

$$CS_{piz}^L = VoT_{pi} \frac{1}{\beta_p} L_{piz} \quad (5.6)$$

The accessibility benefit is measured in terms of consumer surplus, which is expressed in monetary terms as cents (¢) in 2000 dollars. The consumer surplus of the total population can be calculated as a weighted sum of log-sums over a sample of decision makers, where the weights reflect the number of people in the population who face the same representative utilities as the sample. Thus, the consumer surplus for each income category i from each origin zone z is calculated by multiplying the log-sum by the number of trips (A_{piz}) by people in that income category:

$$E(CS_n) = \left(VoT_{pi} \frac{1}{\beta_p} \right) \left[A_{piz} \ln \left(\sum_{j=1}^J e^{\mu_p V_{pijz}} \right) \right] \quad (5.7)$$

where $(VoT_{pi} \cdot 1/\beta_p)$ equates to a negative cost coefficient α_n mentioned in Section 5.2. Therefore, the larger the utility, the larger the log-sum and the larger number of trips results in a larger *negative* consumer surplus. Hence, the larger the *negative* consumer surplus, the *greater* the accessibility.

5.3 Implemented Policy Programs

Two policy programs were implemented in this research. The first is subsidizing transit fare by 50% to see the effect it had on consumer surplus at different income levels. The second is subsidizing driving costs by 50%. Subsidizing the capital cost of vehicle ownership would be interesting to examine, however, the accessibility model used in this study does not take into account capital cost. Also there is a lot of issues with studying capital cost due to the fact that it is a one time payment that is difficult to annualize over the vehicle's life span. And as stated in Chapter 1, low income individuals tend to keep their vehicles for longer which leads to another problem of higher maintenance costs for older vehicles. In the accessibility model, the operation cost of driving is 9.9 cents per mile which includes gas and maintenance costs. Therefore in this research, the operational costs which include fuel and maintenance costs were subsidized by 50% to see the effect it has on consumer surplus.

The change in consumer surplus when implementing these two policies is also plotted for each SMZ at different income levels. These plots show the change in consumer surplus in monetary terms, in 2000 dollars because the analysis was performed

using the MSTM model which also uses 2000 dollars. This change in consumer surplus is measured similar to the study done by de Jong, Daly, Pieters, and ver der Hoorn [2007], method 2.

Consumer surplus is plotted for each SMZ for the various available transportation modes at different income levels available in Appendix B. For a given transportation mode in a given SMZ, the scale is the same at every income level unless noted otherwise; therefore they can be compared. However, the scale between different transportation modes within a SMZ is *not* the same; therefore they *can not* be compared. However, the overall *magnitude* of the consumer surplus *can* be compared across all transportation modes and income levels.

5.4 Analysis Region

Seven TAZs (represented by the green stars in Figure 5.3) were selected within the Washington D.C. Metropolitan Region. These TAZs were selected based on the household value, the concentration of low income individuals or jobs, and the variety of available transportation modes within the TAZ. The selected TAZ and their average household income and value are listed in Table 5.7.

The accessibility measure is calculated using the Maryland Statewide Transportation Model (MSTM), therefore the data is aggregated at statewide modeling zones (SMZs), and thus the corresponding SMZ for the analyzed TAZs are also listed in Table 5.7. The analysis also refers to the alternatives depicted in Figure 5.2 and income levels defined in Table 5.2.

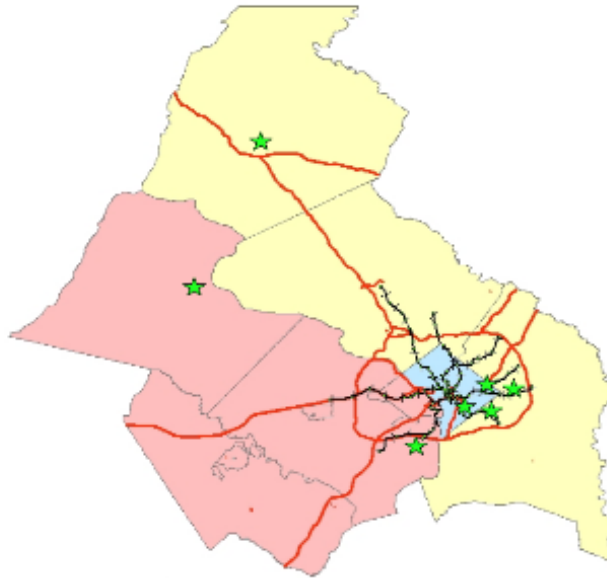


Figure 5.3: Selected TAZs (Green Stars) within Washington D.C., Maryland, and Virginia.

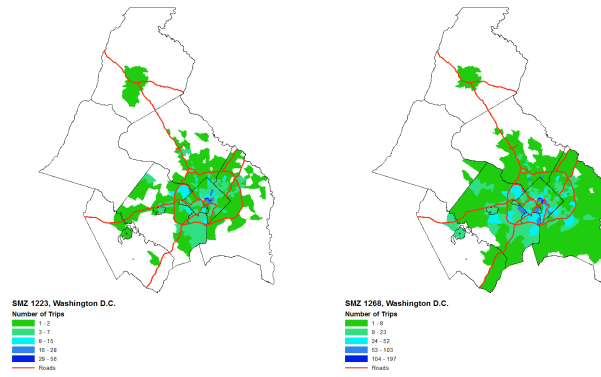
Table 5.7: Statistics About Selected Transportation Analysis Zones.

Location	TAZ	Location	Median HH Income	SMZ
Washington D.C.	219	Rhode Island Ave. Metro	\$28,814	1223
	362	Anacostia Metro	\$19,238	1268
Frederick County, MD	2926	Near I-270 & Rt-70	\$42,529	956
Prince George's County, MD	842	Suitland	\$39,788	813
	1006	Landover, Near Rt-50	\$39,028	796
Fairfax County, VA	2044	Huntington	\$41,277	1317
Loudoun County, VA	2270	Leesburg, Near Rt-267	\$38,231	1368

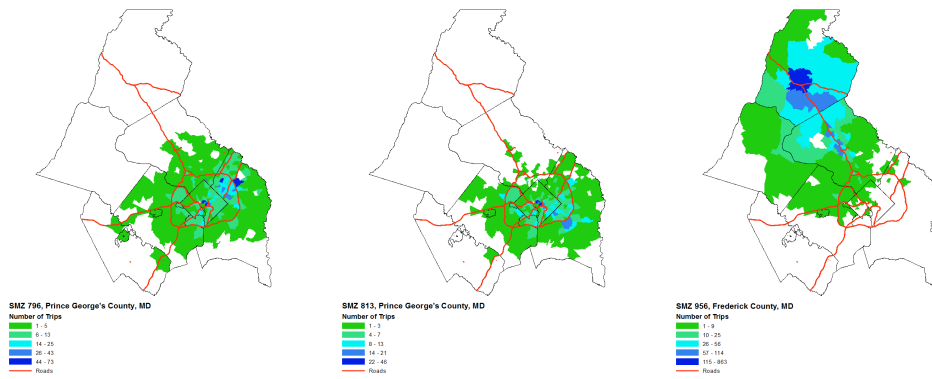
5.4.1 Trips Made

The trips made from each of the seven selected SMZs are mapped in Figure 5.4. The trips made by individuals at income level 1 and 2 with origin in SMZ 1223 and 1268 in Washington D.C. is shown in Figure 5.4(a) and 5.4(b), respectively. As expected, most trips are into downtown Washington D.C. The trips for 796

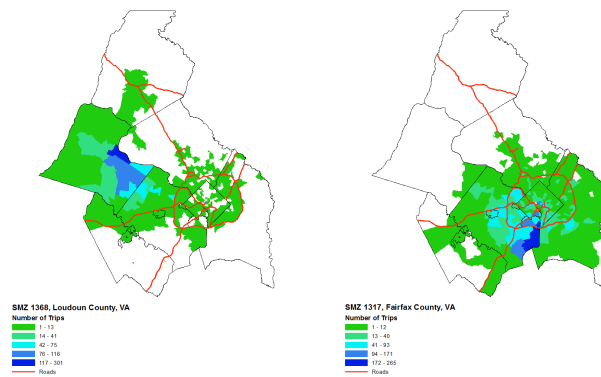
(Landover), 813 (Suitland), and SMZ 956 (Frederick) in Maryland is shown in Figure 5.4(c), 5.4(d), and 5.4(e), respectively. As expected, the trips made from Prince George's County (SMZ 813 and 796) are in Prince George's County or downtown Washington D.C. From Frederic (SMZ 956), most trips are made in Frederick County expanding into Montgomery County along I-270. The trips made for SMZ 1317 and 1368 is shown in Figures 5.4(g) and 5.4(f). Within Fairfax County (SMZ 1317), most trips are made mostly within Fairfax County. And as expected, most trips made from within Loudoun County (SMZ 1368) stay within Loudoun County.



(a) SMZ 1223, Rhode Island Metro, D.C. (b) SMZ 1268, Anacostia Metro, D.C.



(c) SMZ 796, Landover, MD (d) SMZ 813, Suitland, MD (e) SMZ 956, Frederick, MD

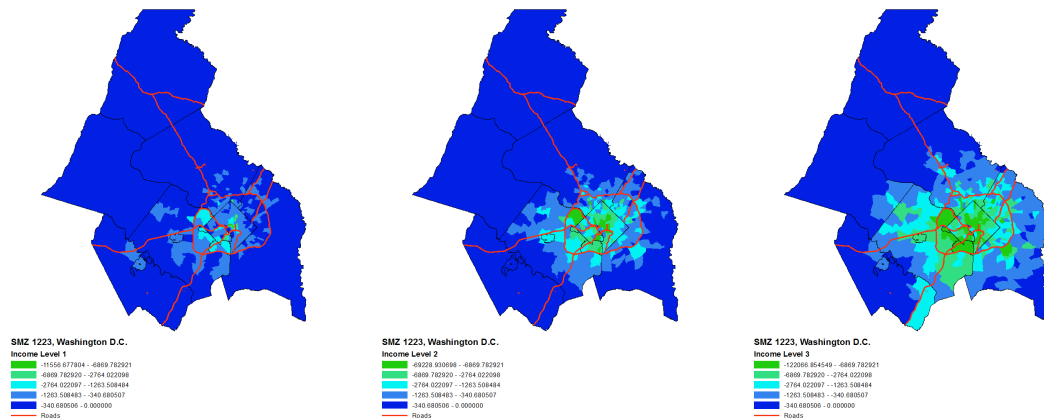


(f) SMZ 1368, Leesburg, VA (g) SMZ 1317, Huntington, VA

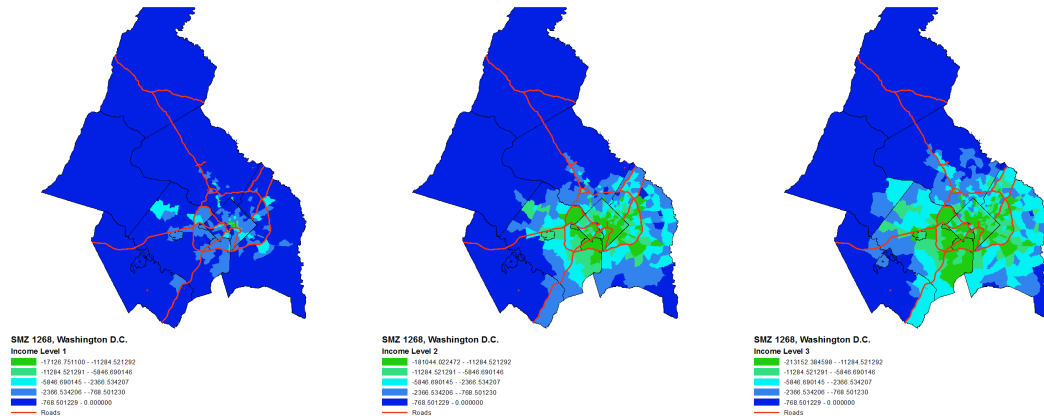
Figure 5.4: Trips Made by Low Income Individuals with Origin in Washington D.C., Maryland, and Virginia.

5.4.2 Income Level

The status quo consumer surplus for all SMZs by income level 1, 2, and 3 are shown in the Figures 5.5 to 5.7. As expected, the accessibility increases as the income level increases, for each SMZ. However, the consumer surplus range varies greatly between the different SMZs with Prince George’s County SMZs (SMZ 956 and 813) having the lowest overall consumer surplus and accessibility.



(a) SMZ 1223, Income Level 1. (b) SMZ 1223, Income Level 2. (c) SMZ 1223, Income Level 3.



(d) SMZ 1268, Income Level 1. (e) SMZ 1268, Income Level 2. (f) SMZ 1268, Income Level 3.

Figure 5.5: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) and 1268 (Anacostia Metro) in Washington D.C.

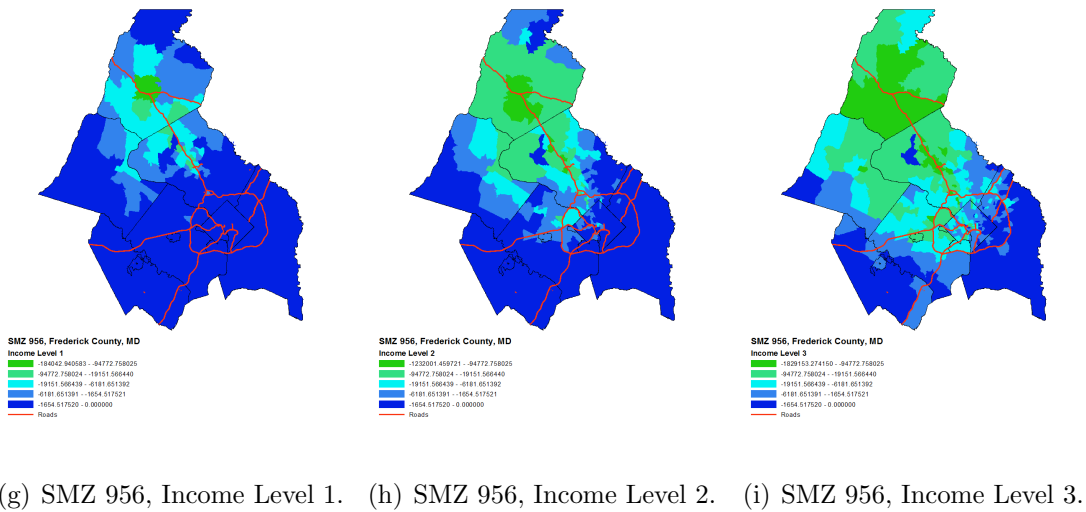
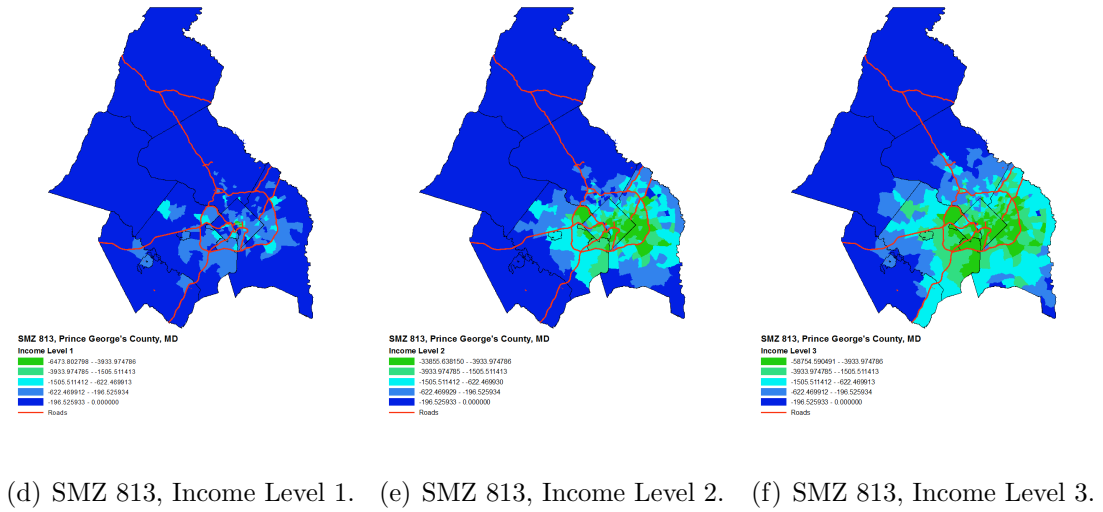
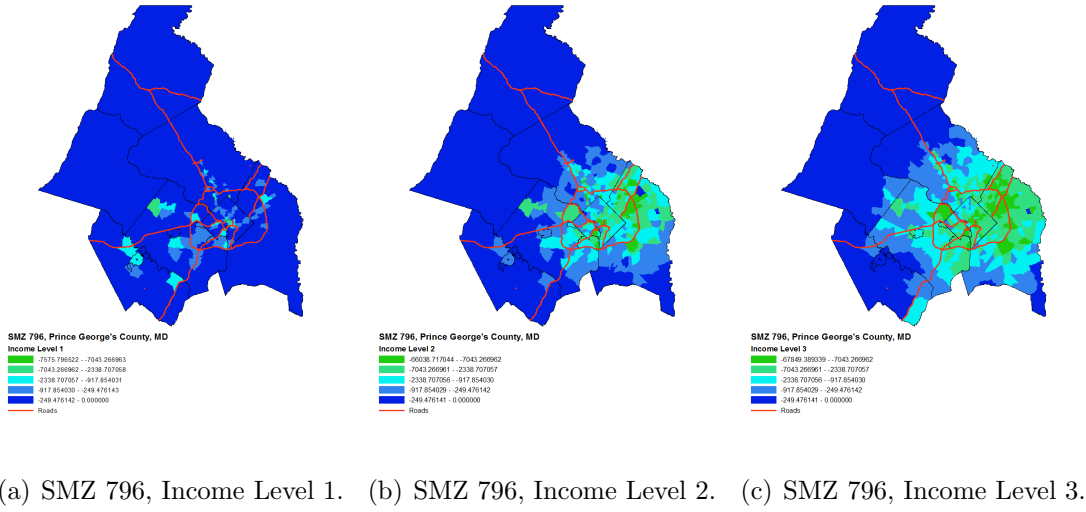
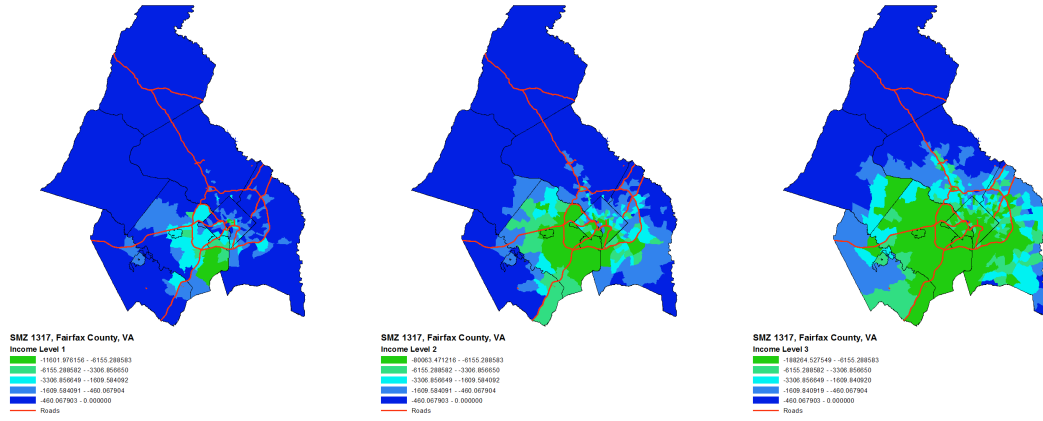
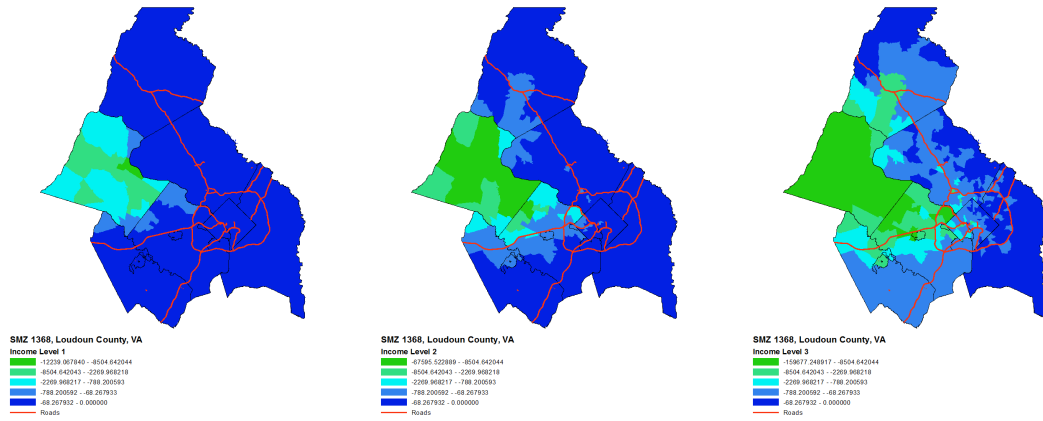


Figure 5.6: Consumer Surplus for SMZ 956 (Frederick), 813 (Suitland), and 796 (Landover) in Maryland.



(a) SMZ 1317, Income Level 1. (b) SMZ 1317, Income Level 2. (c) SMZ 1317, Income Level 3.



(d) SMZ 1368, Income Level 1. (e) SMZ 1368, Income Level 2. (f) SMZ 1368, Income Level 3.

Figure 5.7: Consumer Surplus for SMZ 1317 (Huntington) and 1368 (Leesburg) in Virginia.

5.4.3 Drive Alone

Figures B.1 to B.3 in Appendix B show the consumer surplus for driving alone at income levels 1, 2, and 3. For all SMZs, there is a large difference in driving accessibility between the different income levels. Individuals at income level 1 are less likely to own a vehicle therefore it is expected that they experience the lowest

accessibility.

For SMZ 1223 and 1268 in Washington D.C. at income level 1 and 2, there is higher accessibility for northern Virginia (e.g., Arlington, Alexandria, Fairfax), therefore it is easier to reach northern Virginia by driving than downtown Washington D.C. where most trips are being made. The decreased accessibility within the District can be explained due to the high congestion and other unfavorable driving conditions associated with downtown Washington D.C. For SMZ 813 and 796 in Prince George's County, MD, the consumer surplus seems to be more spread out between Prince George's County, D.C., and northern Virginia. Within Frederick, MD (SMZ 956), there is high accessibility for Frederick and Montgomery County, therefore reaching the District is difficult even when driving. For SMZ 1317 in Fairfax, VA, there is higher accessibility and southern Fairfax County and Prince William's County, than within Washington D.C. and Maryland. For SMZ 1368 in Leesburg, VA, there is higher accessibility to stay within Loudoun County until income level 3, where the accessible regions greatly increases.

The change in consumer surplus when subsidizing operational costs for transportation alternative driving alone is shown in Figure ???. For all SMZs, there is a large increase in consumer surplus between income level 1 and 2. This is also reflective of the fact that individuals in income level 1 are less likely to own a vehicle, therefore subsidizing operational costs will not be helpful to them. Surprisingly the largest SMZ that benefits from subsidized operational costs is in Huntington, VA. Therefore, these individuals have the propensity to drive even though they have access to public transit. Frederick, MD (SMZ 956) and Leesburg, VA (SMZ 1368)

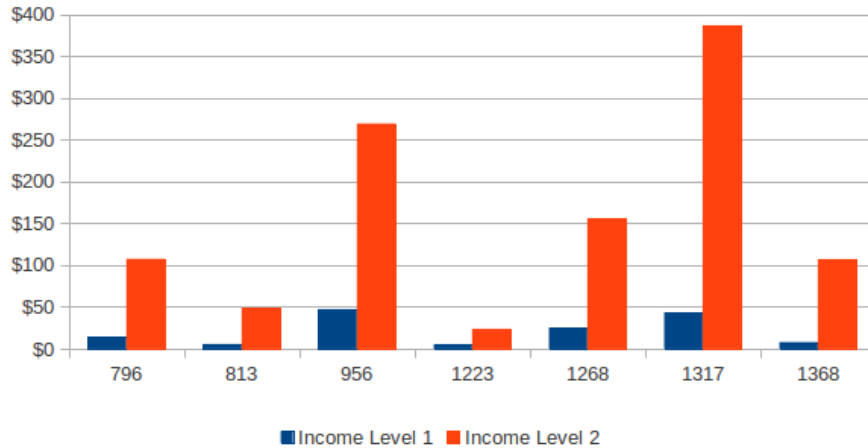


Figure 5.8: Change in Consumer Surplus when Subsidizing Operational Costs for Driving Alone in 2000 Dollars.

has the least available public transportation, therefore, most residents will rely on driving or carpooling. Then, it is expected that these areas would have a large increase in consumer surplus as evident in the figure.

5.4.4 Share Ride

Figures B.4 to B.6 in Appendix B show the consumer surplus for share ride (carpooling) at income levels 1, 2, and 3. Carpooling accessibility patterns are very similar to drive alone accessibility patterns. However, the consumer surplus scale is much smaller than for driving alone, as expected. Again, there is a large carpooling accessibility between the different income levels.

The change in consumer surplus when subsidizing operational costs for transportation alternative share ride (i.e., carpooling) is shown in Figure ???. The same trend is seen for the consumer surplus change in alternative drive alone in the pre-

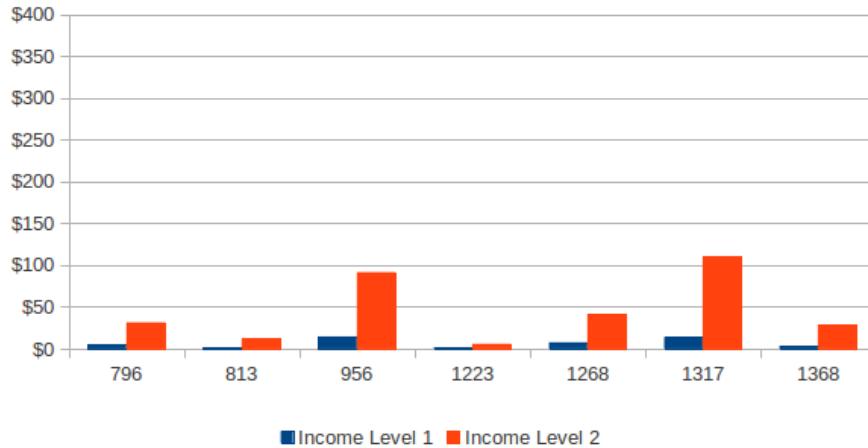


Figure 5.9: Change in Consumer Surplus when Subsidizing Operational Costs for Share Ride (Carpooling) by Income Level in 2000 Dollars.

vious section. This is expected with the similar accessibility patterns in share ride and drive alone. Also there are significantly less carpoolers than drivers, therefore the consumer surplus increase when subsidizing operational costs is expected to be lower than the consumer surplus increase when driving alone.

5.4.5 Bus Transit

The destinations reachable by bus transit only (accessed by walking) is shown in Figures B.7 to B.9 in Appendix B. For all SMZs, an increase in consumer surplus and accessibility is observed with increasing income level. However, for all SMZs except for those within Washington D.C., the areas reached by bus transit accessed by walking decreases with increasing income level. Therefore higher income individuals whom use bus transit tend to travel in shorter distances with grouped together. The SMZs that can access bus by walking are: SMZ 1223 (Washington

D.C.), 1268 (Washington D.C.), 813 (Suitland, MD), 796 (Landover, MD), and 1317 (Huntington, VA). The area reached from SMZ 1223 and 1268 is contained mainly within in the Capital Beltway. The area reached from SMZ 813, Suitland, MD spans Washington D.C. and Prince George’s County. The area reached from SMZ 796, Landover, MD spans the north-east portion of Washington D.C. and Prince George’s County inside the Capital Beltway. The area reached from SMZ 1317, Huntington, VA spans the downtown District and into Fairfax County.

The destinations reachable by bus transit only (accessed by driving) is shown in Figures B.10 to B.12 in Appendix B. Due to limited available parking near bus transit stops, SMZs that can access bus by driving are: SMZ 1268 (Washington D.C.), 956 (Frederick, MD), 796 (Landover, MD), and 1317 (Huntington, VA). For all SMZs, an increase in accessibility is observed with increasing income level. This is especially evident because this transportation alternative requires access by driving, where low income households are less likely to own a vehicle. The area reached from SMZ 1268, Anacostia Metro, D.C. and SMZ 1317, Huntington, VA mainly reaches inside the Capital Beltway with less coverage than when accessing bus transit by walking. Within Frederick, MD (SMZ 956), there is no access to bus transit by walking, however, there is access to bus transit by driving. As expected, those who would drive to take bus transit would travel further and in this case, they travel along the I-270 corridor. That leaves accessibility within the city of Frederick is achieved by driving alone. This will present difficulty for low income households with no vehicles. Those in higher income levels have higher accessibility and travel further away from I-270 and making some trips into downtown Washington D.C. as well.

These individuals may be avoiding traveling along the congested I-270 corridor. The areas reached from SMZ 796 by bus transit accessed by driving is very similar to the those areas reached when accessed by walking.

For some areas, transit may be used in favor of the metro rail system due to its cost and coverage. This is especially true when traveling shorter distances or areas that are not covered by the metro rail system. The accessibility already present in some areas like Washington D.C. and northern Virginia will support the new low income employment growth expected those areas. There is large employment growth expected in the two suburbs of Frederick County, MD and Loudoun County, VA. However, the two suburban SMZs, 956 (Frederick MD) and 1368 (Loudoun County, VA) do not have bus transit that can be accessed by walking. This is a major problem for low income households that do not own vehicles. Therefore, they must rely on other transportation modes like carpooling and other available public transit. For public transportation, bus transit has a higher consumer surplus magnitude than rail transit.

The change in consumer surplus when subsidizing transit fare for the bus transit alternative is shown in Figure 5.10. For all SMZs except SMZ 956 (Frederick, MD) and 1368 (Leesburg, VA), there is a *large* increase in accessibility moving from income level 1 to income 2. Also in these cases, income level 2 has the largest increase in accessibility. Large increases in consumer surplus is seen at income level 2 and 3 indicating that those in income level 2 and 3 are the largest users of bus transit, with income level 2 individuals having making up the biggest share of bus transit riders. Higher income individuals use transit less, therefore the increase

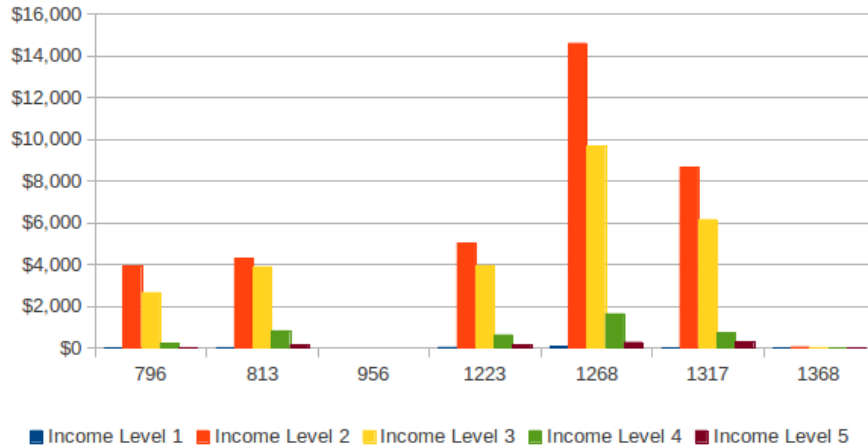


Figure 5.10: Change in Consumer Surplus when Subsidizing Transit Fare for Bus Transit by Income Level in 2000 Dollars.

in accessibility is less for increasing income levels. Frederick, MD (SMZ 956) and Leesburg, VA (SMZ 1368) have already shown to have little to no bus transit, therefore they would not benefit much from subsidizing transit fare until a public transit system is implemented there.

5.4.6 Rail Transit

The destinations reachable by rail transit only (accessed by walking) is shown in Figures B.13 to B.15 in Appendix B. For all SMZs, an increase in consumer surplus and accessibility is observed with increasing income level. However, for all SMZs the areas reached by rail transit accessed by walking decreases with increasing income level. The SMZs that can access rail transit by walking are: SMZ 1223 (Washington D.C.), 1268 (Washington D.C.), 813 (Suitland, MD), 796 (Landover, MD), and 1317 (Huntington, VA). The area reached from SMZ 1223 (next to Rhode

Island Metro station) and 1268 (next to Anacostia Metro station) is mostly outside of the Capital Beltway. The areas reached from SMZ 813 (approximately 1.5 miles from Suitland Metro station) and 796 (approximately 3 miles from the New Carrollton Metro station) includes areas inside and outside of the Capital Beltway. However, those from Landover, MD (SMZ 796) and Suitland, MD (SMZ 813) do not travel in areas north of Landover and Suitland and further south into Prince George's County. The area reached from SMZ 1317 (less than 2 miles from the Huntington Metro station) covers the entire inside of the beltway, into Prince George's and Montgonmery County and along major corridors (I-270 and somewhat, I-66).

The destinations reachable by rail transit only (accessed by driving) is shown in Figures B.16 to B.18 in Appendix B. Due to limited available parking near rail transit stops, SMZs that can access rail by driving are: SMZ 1268 (Washington D.C.), 956 (Frederick, MD), 796 (Landover, MD), and 1317 (Huntington, VA). For all SMZs, an increase in accessibility is observed with increasing income level. This can be explained by the fact that rail transit is less accessible to low income individuals due to their cost and the fact that this alternative is accessed by driving to a metro station. Only the further most metro rail stations, almost exclusively outside the Capital Beltway and along major corridors (i.e., I-270 and I-66) are reached by rail transit accessed by driving.

The destinations reachable by commuter rail transit only (accsed by walking or driving) is shown in Figures B.19 to B.22 in Appendix B. There are very few SMZs that can access commuter rail by walking or driving. The SMZs that can access commuter rail by walking are: SMZ 1223 (Washington D.C.), 1268 (Washington

D.C.), 813 (Suitland, MD), 796 (Landover, MD), and 1317 (Huntington, VA), which can be accessed by walking or driving. This alternative does not include transferring from rail to commuter rail. The destinations reached on commuter rail is expected because the nearest commuter rail line is the MARC commuter rail service.

It should be noted that in Leesburg, VA in Loudoun County (SMZ 1368), there is no consumer surplus for *any* public transit mode, be it: bus, express bus, rail, or commuter rail being accessed by walking or driving. This is expected as the closest metro rail station is over 20 miles away. Loudoun County is expecting a lot of low income employment growth and the consumer surplus and accessibility of Loudoun county is *much* less than other observed SMZs due to its lack of available public transit services. Therefore, low income individuals that live within Leesburg would need to have a vehicle to access anywhere. If low income households have no vehicles, this is especially problematic in Loudoun County. However, when looking at the accessibility of driving and carpooling, it isn't until income level 3 that the destination region is reached. Therefore, even if low income households own a vehicle, they may not be able to reach their destination if it is too far outside of Loudoun County.

For all SMZs, the destinations reachable by rail transit accessed by walking is the inverse of their respective destinations reachable by bus transit accessed by walking. Therefore, within the downtown District, it is easier to travel by bus transit, and further distances is more easily achieved by rail transit. Those in higher income levels have a higher consumer surplus for rail transit that follow along major corridors (i.e., I-270, I-95, and I-66). The higher consumer surplus and accessibility

for higher income levels corresponds to the idea that rail users are discretionary riders Chapter 1. In combination with bus transit, the region where most trips are being made for most SMZs is covered, except for the more outlying suburbs (i.e., Frederick County, MD, Loudoun County, VA, and Prince William’s County, VA). These are also the areas where there is a large low income employment growth is expected. Low income individuals who want to access these areas must then rely on carpooling or driving. This is problematic for low income households with no vehicles.

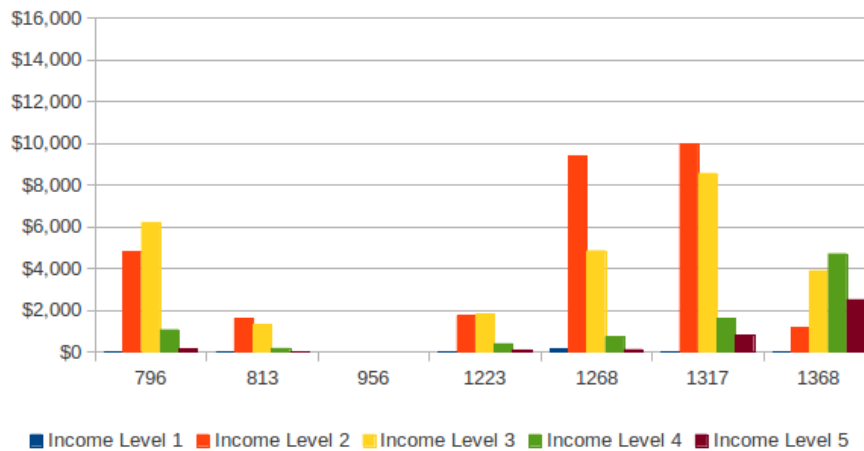


Figure 5.11: Change in Consumer Surplus when Subsidizing Transit Fare for Rail Transit by Income Level in 2000 Dollars.

The change in consumer surplus when subsidizing transit fare for the rail transit alternative is shown in Figure 5.11. For all SMZs except SMZ 956 (Frederick, MD) there is a *large* increase in consumer surplus moving from income level 1 to income 2. Also in these cases, income level 2 has the largest increase in consumer surplus. Large consumer surplus is seen at income level 2 and 3 indicating that

those in income level 2 and 3 are the largest users of rail transit, with income level 2 individuals having making up the biggest share of rail transit riders. Higher income individuals use transit less, therefore the increase in accessibility is less for increasing income levels. Frederick, MD (SMZ 956) have already shown to have no rail transit, therefore they would not benefit much from subsidizing transit fare until a public rail transit system is implemented there. The overall consumer surplus increase for rail transit is less than the consumer surplus increase seen in bus transit.

5.5 Policy Analysis Conclusions

Subsidizing operational costs does not increase the accessibility for individuals at income level 1 nearly as much as for those at income level 2. This is also reflective of the fact that individuals in income level 1 are less likely to own a vehicle, therefore subsidizing operational costs will not be helpful to them. Those living in areas with the least available public transportation (i.e., Frederick, MD and Leesburg, VA) see a large increase in accessibility.

Subsidizing transit fare does not increase the accessibility for individuals at income level 1. These individuals are not traveling much in general, therefore they would not benefit from the reduced fare. Individuals at income level 2 sees the largest increase in accessibility. A large increase in accessibility is also seen at income level 3, indicating that individuals in income levels 2 and 3 are the largest users of bus and rail transit. Areas with little to no rail or bus transit (i.e., Frederick, MD and Leesburg, VA) would not benefit from subsidized transit fare.

Chapter 6

Conclusions and Discussions

A large percentage of low income households are found in: the District of Columbia, Montgomery County, Prince George's County, and Fairfax County. From the forecast of low income employment, it can be seen that a majority of employment growth is seen in the suburban areas and counties surrounding Washington D.C. These can be seen in: Loudoun County, Prince Williams County, and Frederick County. This employment growth is also spatial clustered around major corridors like Interstate-270 and Interstate-66. These job growth locations do not coincide with where low income workers current live; therefore, low income individuals may need to travel even further to obtain these jobs, making this highly problematic. This alludes to the possibility of a spatial mismatch between where low income individuals live and where they work.

Looking at the trip patterns of low income individuals, it is apparent that low income individuals spend more time traveling shorter distances. This is explained by the large larger portion of low income individuals that use slower transportation modes including walking, biking, and especially public transit. A larger portion of transit users are low income transit captives, therefore more low income individuals rely on the existing public transportation system. The typical recommendation for urban areas with some level of connectivity via public transportation is to subsidize

public transportation. In this case, subsidizing public transit fare and subsidizing operational costs were analyzed.

Subsidizing operation costs did not increase accessibility for those of *very* low income. This is expected as those in this income level are much more unlikely to own a vehicle in the first place. Subsidizing transit fare also does not increase accessibility for individuals for those of *very* low income. This can be explained by the fact that individuals in this income level (i.e., income level 1) do not travel very much in the first place. However, there is large increase in accessibility for those at slightly higher income levels. Areas with little or no available public transit see no benefit for this subsidization. Even with the increased accessibility from subsidizing transit fare, there is still the problem that certain areas are still not being reached. Therefore low income individuals in the District of Columbia, Montgomery County, Prince George's County, and Fairfax County will have trouble reaching the job growth in Loudoun County, Prince William's County, and Frederick County.

6.1 Future Work

The lack of connectivity of suburban counties limits the job accessibility for low income individuals. Therefore, specifically focusing on connecting these outer suburban counties creating a connected public transit network would be beneficial to increasing accessibility for the expected job growth. Also, future studies should measure the change in consumer surplus and accessibility when subsidizing the capital cost of owning a vehicle, rather than subsidizing marginal operational costs.

Appendix A

Statistical Analysis of Low Income Households and Individuals

Table A.1: Low Income Household Percentages in Washington D.C.

PUMA	Overall Distribution within D.C.			Distribution within PUMA		
	Not Low Income	Low Income	Total	Not Low Income	Low Income	Total
00101	16.4%	1.3%	17.7%	92.5%	7.5%	100%
00102	13.9%	2.8%	16.7%	83.0%	17.0%	100%
00103	15.9%	3.7%	19.6%	81.2%	18.8%	100%
00104	15.2%	6.8%	21.9%	69.2%	30.8%	100%
00105	19.8%	4.3%	24.1%	82.2%	17.8%	100%
Overall	81.1%	18.9%	100%	81.1%	18.9%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.2: Low Income Household Percentages in Maryland.

PUMA	Overall Distribution within MD.			Distribution within PUMA		
	Not Low Income	Low Income	Total	Not Low Income	Low Income	Total
00300	10.3%	1.0%	11.3%	91.5%	8.5%	100%
01001	5.2%	0.3%	5.5%	95.4%	4.6%	100%
01002	5.5%	0.5%	6.1%	91.2%	8.5%	100%
01003	7.8%	0.7%	8.6%	91.5%	8.5%	100%
01004	9.1%	0.5%	9.7%	94.5%	5.5%	100%
01005	5.6%	0.8%	6.4%	87.3%	12.7%	100%
01006	5.0%	0.6%	5.5%	89.8%	10.2%	100%
01007	5.0%	0.7%	5.7%	87.8%	12.2%	100%
01101	3.7%	0.8%	4.5%	81.2%	17.9%	100%
01102	6.0%	0.5%	6.5%	91.7%	8.3%	100%
01103	4.2%	0.8%	5.0%	84.1%	15.9%	100%
01104	4.3%	0.7%	5.0%	85.5%	14.5%	100%
01105	7.4%	0.3%	7.8%	95.6%	4.4%	100%
01106	6.3%	0.4%	6.7%	93.8%	6.2%	100%
01107	5.1%	0.7%	5.8%	87.9%	12.1%	100%
Overall	90.6%	9.4%	100%	90.6%	9.4%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.3: Low Income Household Percentages in Virginia.

PUMA	Overall Distribution within VA.			Distribution within PUMA		
	Not Low Income	Low Income	Total	Not Low Income	Low Income	Total
00100	10.4%	1.0%	11.4%	91.4%	8.6%	100%
00200	7.3%	0.7%	8.0%	91.1%	8.9%	100%
00301	8.7%	0.9%	9.6%	91.0%	9.0%	100%
00302	8.1%	0.7%	8.8%	91.8%	8.2%	100%
00303	7.8%	0.4%	8.2%	94.8%	5.2%	100%
00304	6.7%	0.4%	7.0%	94.4%	5.6%	100%
00305	12.3%	0.7%	13.0%	94.4%	5.6%	100%
00501	7.5%	0.6%	8.2%	92.2%	7.8%	100%
00502	8.1%	0.7%	8.8%	91.9%	8.1%	100%
00600	15.8%	1.2%	17.0%	92.9%	7.1%	100%
Overall	92.6%	7.4%	100%	92.6%	7.4%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.4: Labor Force Distribution in Washington D.C.

PUMA	At Least 1 Householder in the Labor Force	Couple Neither in the Labor Force	Single Female Head of Household Not in the Labor Force	Single Male Head of Household Not in the Labor Force	Total
00101	30.4%	44.6%	22.5%	2.5%	100%
00102	63.4%	6.0%	24.8%	5.7%	100%
00103	49.2%	10.5%	32.5%	7.8%	100%
00104	50.8%	4.8%	40.5%	3.9%	100%
00105	57.4%	7.8%	30.2%	4.6%	100%
Overall	52.9%	7.3%	34.9%	4.9%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.5: Labor Force Distribution in Maryland.

PUMA	At Least 1 Householder in the Labor Force	Couple Neither in the Labor Force	Single Female Head of Household Not in the Labor Force	Single Male Head of Household Not in the Labor Force	Total
00300	70.8%	11.0%	17.6%	0.7%	100%
01001	57.2%	20.1%	22.7%	0.0%	100%
01002	81.6%	1.5%	14.6%	2.3%	100%
01003	71.7%	12.0%	13.0%	3.4%	100%
01004	56.4%	30.3%	8.9%	4.4%	100%
01005	76.3%	11.7%	8.6%	3.5%	100%
01006	73.6%	11.8%	12.9%	1.7%	100%
01007	86.4%	5.1%	7.0%	1.5%	100%
01101	84.7%	5.3%	7.6%	2.5%	100%
01102	76.6%	8.1%	13.6%	1.8%	100%
01103	79.9%	7.0%	10.0%	3.1%	100%
01104	59.4%	4.1%	29.6%	6.9%	100%
01105	58.5%	16.1%	19.2%	6.2%	100%
01106	50.7%	20.7%	27.2%	1.3%	100%
01107	69.7%	4.7%	21.5%	4.2%	100%
Overall	72.3%	9.7%	15.1%	2.9%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.6: Labor Force Distribution in Virginia.

PUMA	At Least 1 Householder in the Labor Force	Couple Neither in the Labor Force	Single Female Head of Household Not in the Labor Force	Single Male Head of Household Not in the Labor Force	Total
00100	76.9%	8.6%	12.6%	1.9%	100%
00200	71.9%	9.0%	17.4%	1.7%	100%
00301	71.7%	15.2%	11.4%	1.7%	100%
00302	75.1%	8.2%	16.1%	0.6%	100%
00303	79.9%	6.7%	11.5%	1.9%	100%
00304	71.8%	13.2%	8.0%	7.0%	100%
00305	67.8%	19.6%	12.6%	0.0%	100%
00501	78.2%	8.9%	12.3%	0.6%	100%
00502	77.7%	7.5%	14.2%	0.6%	100%
00600	69.9%	15.3%	12.6%	2.2%	100%
Overall	73.9%	11.4%	13.0%	1.6%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.7: Distribution of Low Income Household Size in Washington D.C.

PUMA	1	2	3	4	5	6+	Total
00101	66.9%	22.2%	5.1%	4.3%	1.4%	0.0%	100%
00102	55.0%	18.5%	9.2%	9.6%	4.9%	2.8%	100%
00103	53.4%	19.2%	10.6%	6.4%	6.7%	3.8%	100%
00104	38.0%	21.5%	13.6%	14.7%	6.2%	6.1%	100%
00105	65.4%	17.6%	7.6%	5.2%	2.2%	2.0%	100%
Overall	51.8%	19.8%	10.4%	9.4%	4.8%	3.8%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.8: Distribution of Low Income Household Size in Maryland.

PUMA	1	2	3	4	5	6+	Total
00300	44.4%	19.1%	13.2%	10.6%	9.2%	3.4%	100%
01001	28.6%	27.2%	21.9%	12.3%	6.4%	3.5%	100%
01002	24.7%	15.4%	24.1%	12.9%	14.4%	8.5%	100%
01003	39.4%	24.6%	11.5%	12.1%	8.7%	3.7%	100%
01004	1.9%	16.7%	11.9%	4.9%	2.3%	2.3%	100%
01005	36.5%	18.9%	13.2%	14.2%	7.6%	9.6%	100%
01006	35.1%	17.1%	18.0%	14.5%	11.1%	4.2%	100%
01007	48.3%	20.7%	9.6%	10.4%	5.8%	5.1%	100%
01101	27.2%	23.6%	7.2%	15.1%	11.7%	5.0%	100%
01102	44.5%	13.2%	16.1%	9.7%	9.0%	7.4%	100%
01103	42.4%	13.9%	10.7%	10.7%	10.0%	12.3%	100%
01104	38.1%	19.1%	15.5%	11.1%	7.8%	8.4%	100%
01105	47.5%	23.6%	7.7%	12.1%	2.3%	6.8%	100%
01106	53.9%	19.6%	9.9%	7.2%	4.7%	4.6%	100%
01107	43.2%	20.4%	15.2%	9.4%	6.1%	5.8%	100%
Overall	40.8%	19.3%	14.2%	11.3%	8.2%	6.2%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.9: Distribution of Low Income Household Size in Virginia.

PUMA	1	2	3	4	5	6	Total
00100	51.6%	18.6%	12.7%	11.1%	3.1%	2.9%	100%
00200	47.3%	19.5%	13.4%	11.8%	4.4%	3.5%	100%
00301	38.3%	18.4%	15.0%	14.8%	5.9%	7.6%	100%
00302	34.0%	16.6%	18.0%	16.1%	5.8%	9.4%	100%
00303	35.2%	8.4%	17.3%	23.2%	10.2%	5.7%	100%
00304	26.1%	16.8%	17.3%	21.7%	8.2%	10.0%	100%
00305	45.5%	18.7%	12.4%	10.2%	7.8%	5.5%	100%
00501	23.5%	15.3%	18.0%	19.6%	13.9%	9.6%	100%
00502	26.7%	17.0%	12.9%	18.1%	13.3%	11.9%	100%
00600	44.4%	20.9%	13.1%	11.2%	5.6%	4.8%	100%
Overall	39.0%	17.7%	14.6%	14.7%	7.3%	6.7%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.10: Income-to-Rent Ratio of Low Income Households in Washington D.C.

PUMA	0-20%	21-40%	41-60%	61-80%	81-100%	>100%	Total
00101	0.0%	4.7%	3.5%	6.1%	4.1%	81.6%	100%
00102	3.8%	18.2%	19.2%	14.9%	11.7%	32.2%	100%
00103	4.6%	26.8%	15.8%	14.4%	7.1%	31.4%	100%
00104	0.6%	20.7%	19.4%	13.4%	7.5%	29.5%	100%
00105	5.6%	21.8%	9.7%	7.3%	7.3%	48.4%	100%
Overall	6.3%	20.8%	15.5%	11.9%	7.8%	37.8%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.11: Income-to-Rent Ratio of Low Income Households in Maryland.

PUMA	0-20%	21-40%	41-60%	61-80%	81-100%	>100%	Total
00300	5.7%	23.0%	22.3%	10.3%	7.4%	31.4%	100%
01001	0.0%	18.5%	15.6%	17.6%	12.0%	36.3%	100%
01002	1.0%	12.1%	12.5%	18.8%	10.3%	45.3%	100%
01003	1.4%	18.1%	15.5%	11.8%	13.7%	39.5%	100%
01004	6.8%	12.6%	5.7%	13.7%	12.2%	49.0%	100%
01005	2.6%	19.1%	22.2%	17.2%	7.3%	31.6%	100%
01006	2.5%	9.0%	11.8%	16.6%	7.1%	53.0%	100%
01007	2.0%	14.5%	17.4%	8.8%	15.3%	42.1%	100%
01101	1.8%	8.5%	18.5%	18.4%	12.6%	40.3%	100%
01102	1.1%	12.3%	15.9%	20.7%	9.0%	40.9%	100%
01103	0.3%	21.0%	14.2%	20.3%	16.7%	27.4%	100%
01104	1.5%	15.7%	12.7%	25.0%	8.8%	36.3%	100%
01105	0.0%	18.6%	0.4%	19.5%	11.8%	49.7%	100%
01106	5.5%	26.9%	10.1%	13.8%	9.7%	34.0%	100%
01107	3.0%	12.7%	21.9%	21.3%	9.7%	31.4%	100%
Overall	2.4%	15.4%	16.2%	16.8%	11.1%	38.2%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.12: Income-to-Rent Ratio of Low Income Households in Virginia.

PUMA	0-20%	21-40%	41-60%	61-80%	81-100%	>100%	Total
00100	1.6%	16.9%	10.6%	14.3%	11.6%	45.0%	100%
00200	1.2%	15.7%	19.5%	10.7%	12.7%	40.3%	100%
00301	6.7%	17.9%	13.5%	19.1%	15.1%	27.8%	100%
00302	1.0%	16.4%	20.2%	21.9%	9.2%	31.3%	100%
00303	5.0%	9.7%	9.2%	12.7%	10.5%	52.9%	100%
00304	3.5%	10.8%	10.5%	5.2%	2.4%	67.5%	100%
00305	3.6%	19.3%	13.5%	12.3%	14.8%	36.6%	100%
00501	0.8%	10.1%	15.9%	18.9%	6.0%	48.4%	100%
00502	2.6%	15.0%	12.1%	18.8%	18.5%	33%	100%
00600	1.9%	18.0%	18.6%	15.1%	11.2%	35.3%	100%
Overall	2.6%	15.8%	14.8%	15.4%	12.0%	39.3%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.13: Labor Force Participation of Low Income Individuals in Washington

D.C.

PUMA	Employed	Unemployed	Not in the Labor Force	Total
00101	26.2%	3.6%	70.2%	100%
00102	32.9%	11.9%	55.2%	100%
00103	23.6%	11.2%	65.2%	100%
00104	21.6%	15.7%	62.8%	100%
00105	27.9%	9.8%	62.3%	100%
Overall	25.6%	11.2%	63.3%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.14: Labor Force Participation of Low Income Individuals in Maryland.

PUMA	Employed	Unemployed	Not in the Labor Force	Total
00300	33.4%	7.3%	59.3%	100%
01001	25.3%	11.0%	63.7%	100%
01002	50.0%	11.7%	38.2%	100%
01003	32.8%	6.1%	61.2%	100%
01004	28.8%	4.0%	67.3%	100%
01005	35.6%	12.8%	51.6%	100%
01006	35.0%	9.4%	55.6%	100%
01007	46.5%	11.3%	42.2%	100%
01101	39.1%	8.7%	52.2%	100%
01102	39.6%	11.0%	49.5%	100%
01103	33.5%	11.1%	55.3%	100%
01104	31.3%	18.8%	49.9%	100%
01105	23.8%	4.8%	71.4%	100%
01106	22.8%	10.6%	66.6%	100%
01107	39.0%	16.3%	44.7%	100%
Overall	35.4%	10.1%	54.5%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Table A.15: Labor Force Participation of Low Income Individuals in Virginia.

PUMA	Employed	Unemployed	Not in the Labor Force	Total
00100	43.9%	5.2%	50.9%	100%
00200	35.3%	9.3%	55.4%	100%
00301	39.4%	7.7%	52.9%	100%
00302	40.3%	10.1%	49.5%	100%
00303	38.5%	7.6%	53.9%	100%
00304	41.1%	8.1%	50.8%	100%
00305	37.6%	7.9%	54.5%	100%
00501	41.3%	8.8%	49.8%	100%
00502	54.8%	7.4%	37.9%	100%
00600	36.1%	9.7%	54.2%	100%
Overall	40.9%	8.2%	51.0%	100%

Source: American Community Survey 2006-2010, 5-year Estimates

Appendix B

Policy Analysis Figures

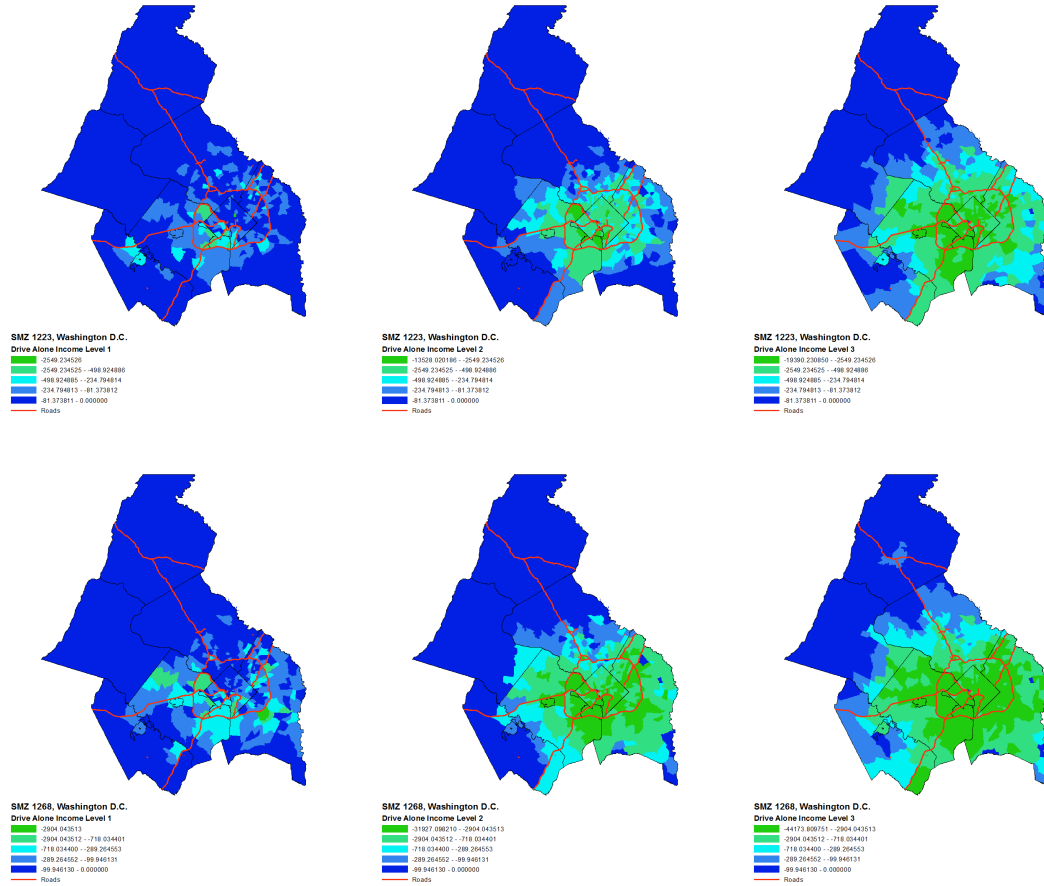


Figure B.1: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) and 1268 (Anacostia Metro) in Washington D.C. for Driving Alone.

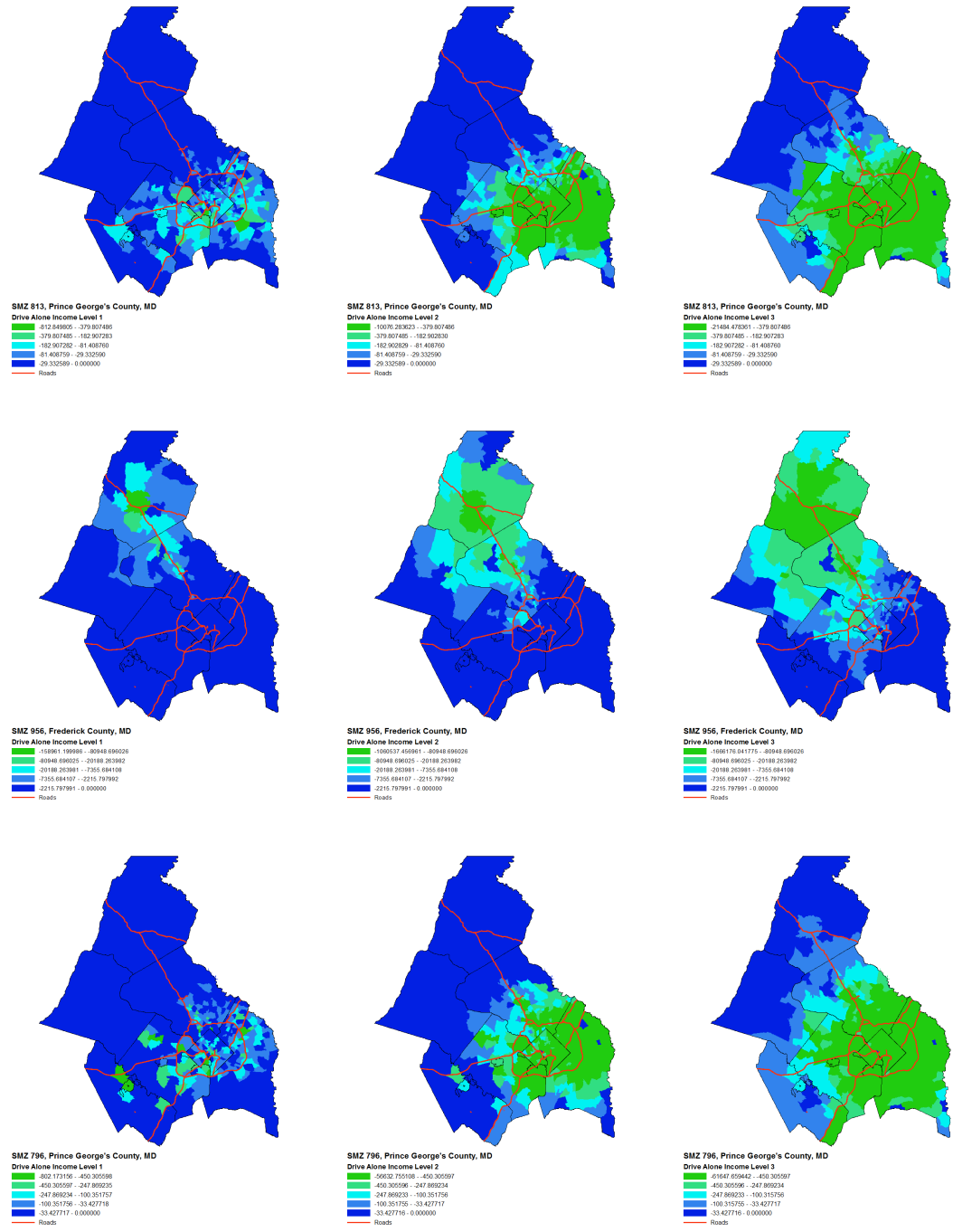


Figure B.2: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 796 (Landover), 813 (Suitland), and 956 (Frederick) in Maryland for Drive Alone.

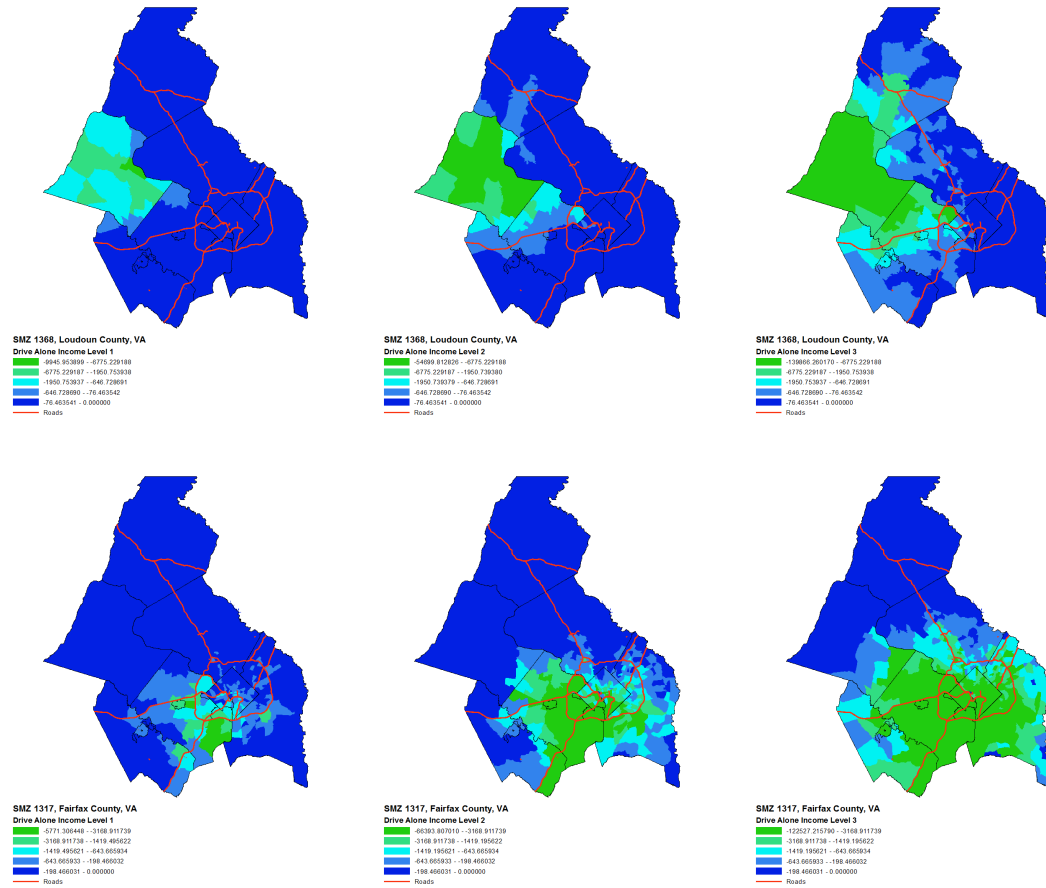


Figure B.3: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) and 1368 (Leesburg) in Virginia for Drive Alone.

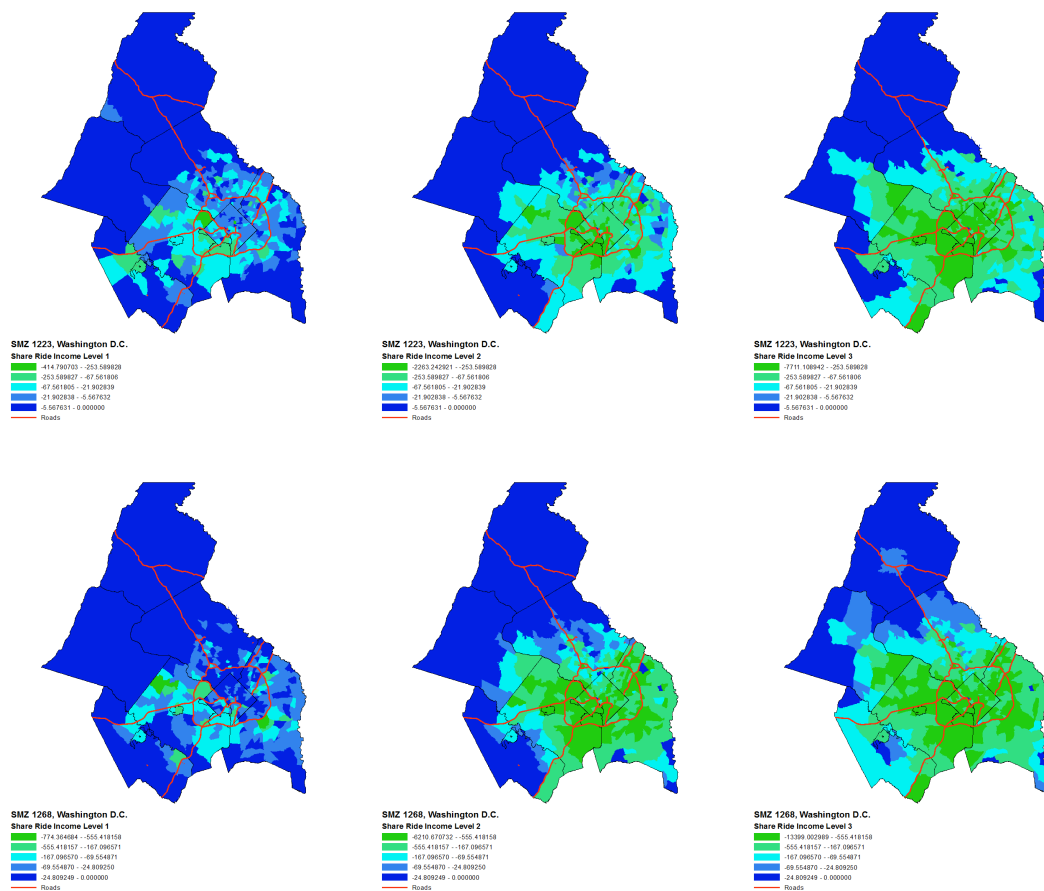


Figure B.4: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) and 1268 (Anacostia Metro) in Washington D.C. for Share Ride (Car-pooling).

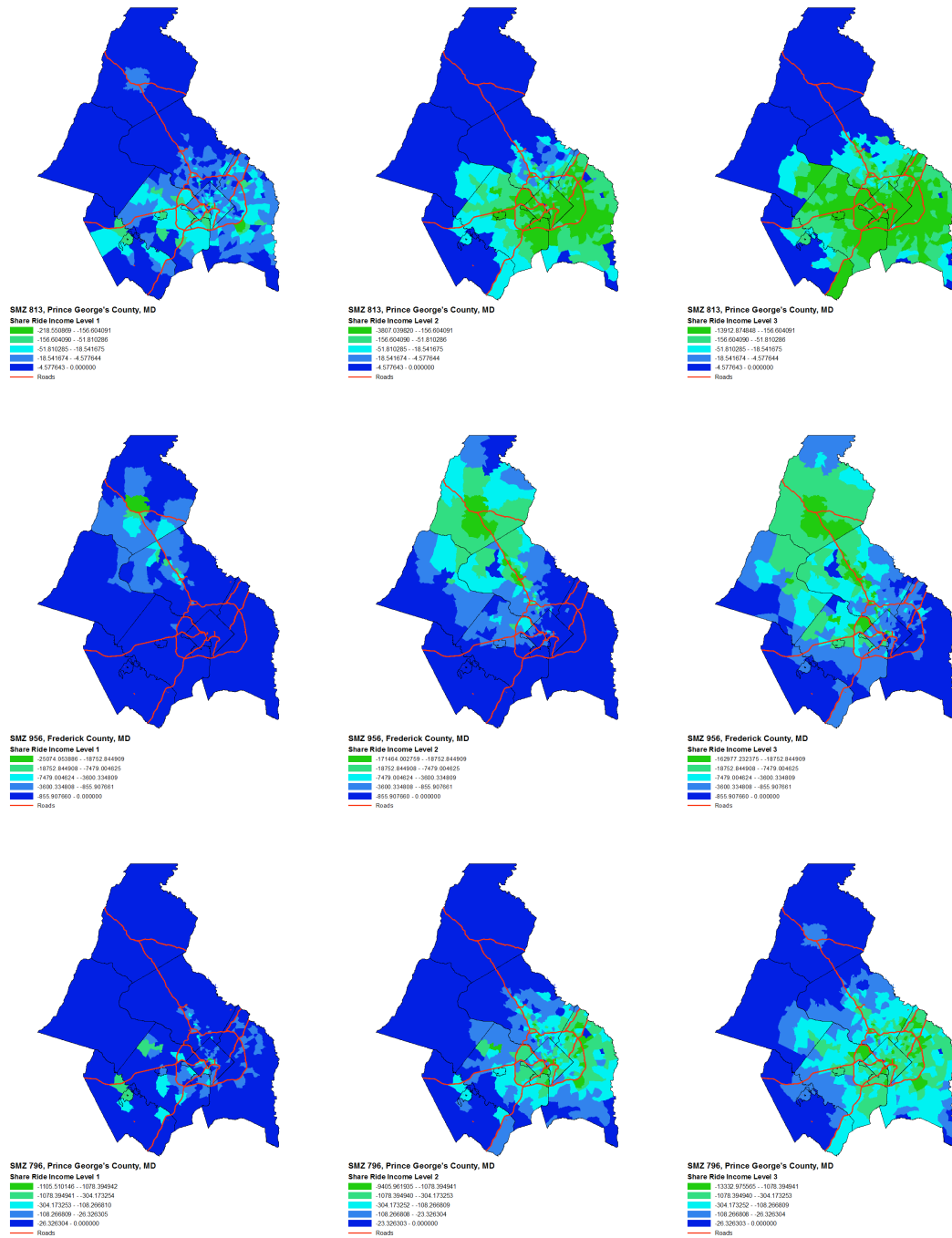


Figure B.5: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 796 (Landover), 813 (Suitland), and 956 (Frederick) in Maryland for Share Ride (Carpooling).

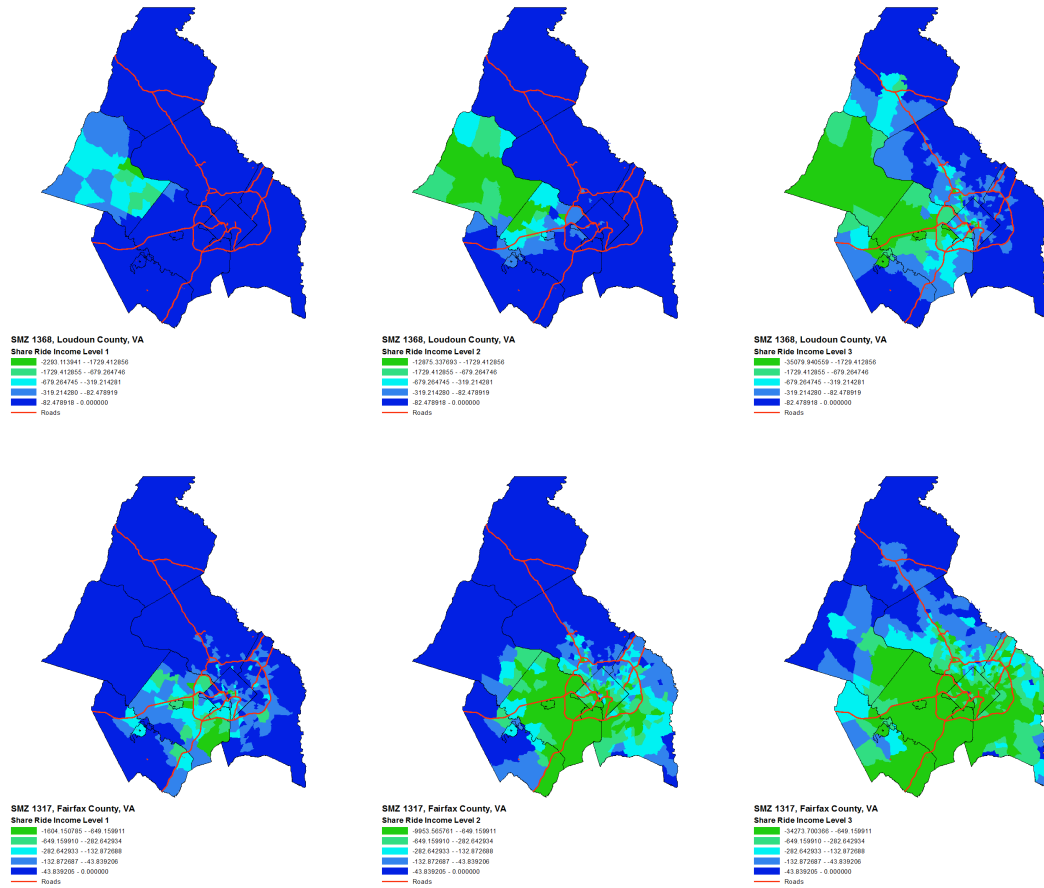


Figure B.6: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) and 1368 (Leesburg) in Virginia for Share Ride (Carpooling).

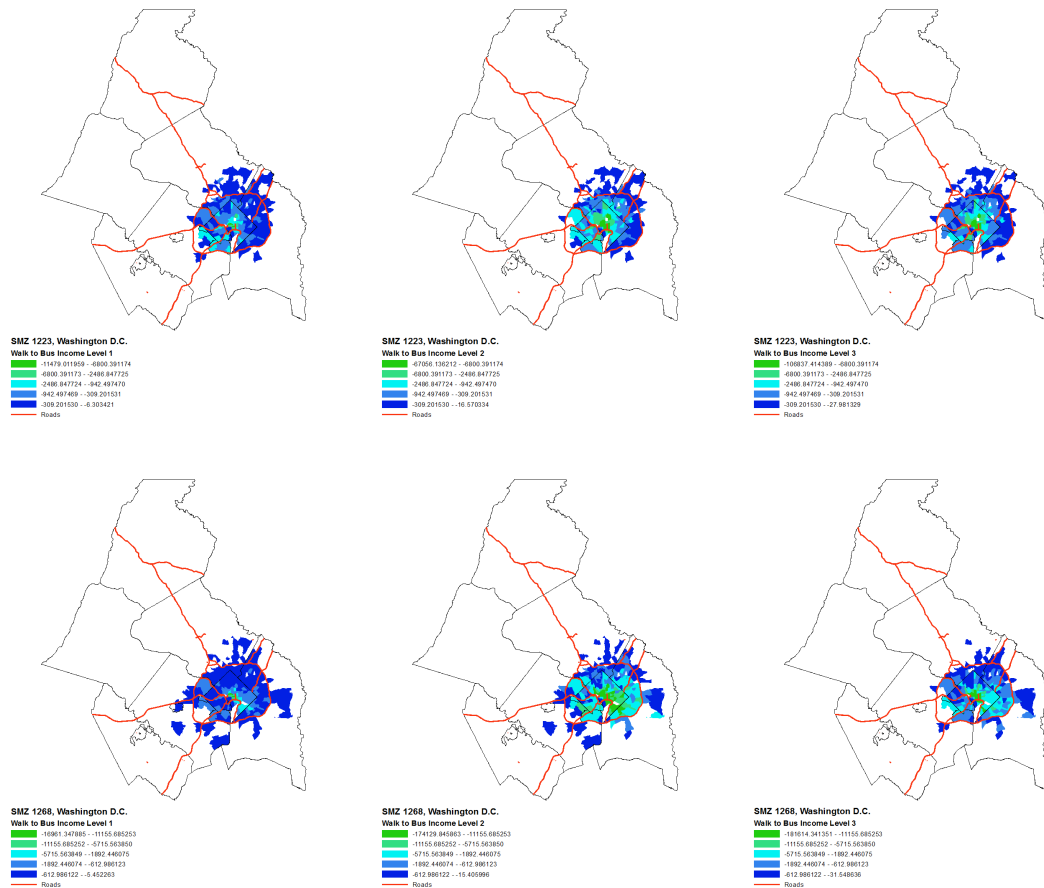


Figure B.7: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) and 1268 (Anacostia Metro) in Washington D.C. for Walk to Bus Transit.

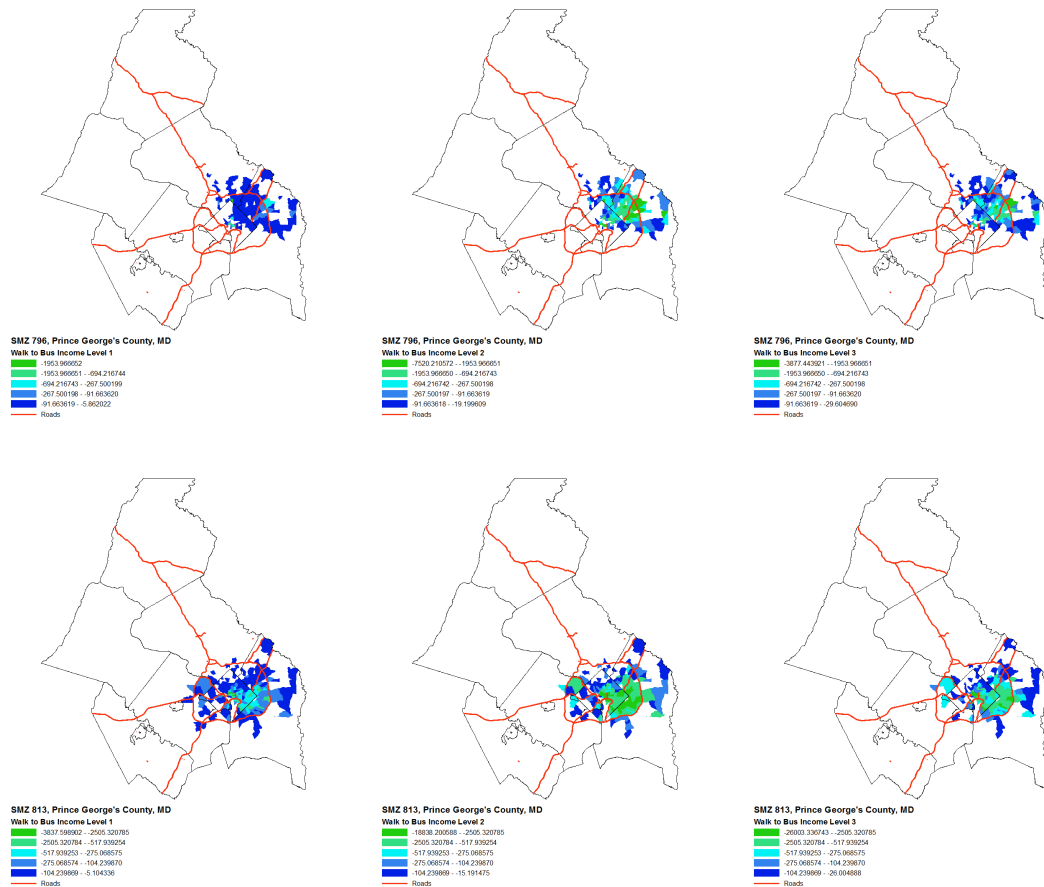


Figure B.8: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 796 (Landover) and 813 (Suitland) in Maryland for Walk to Bus Transit.

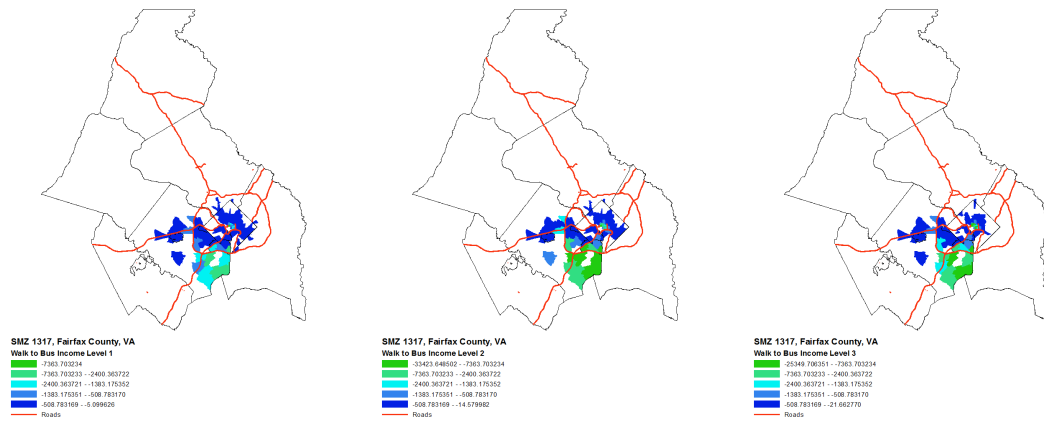


Figure B.9: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) in Virginia for Walk to Bus.

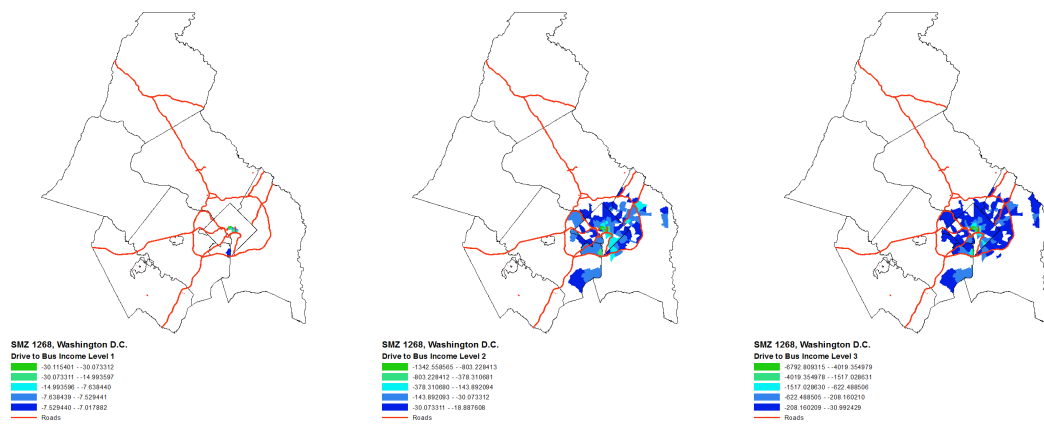


Figure B.10: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) in Washington D.C. for Drive to Bus Transit.

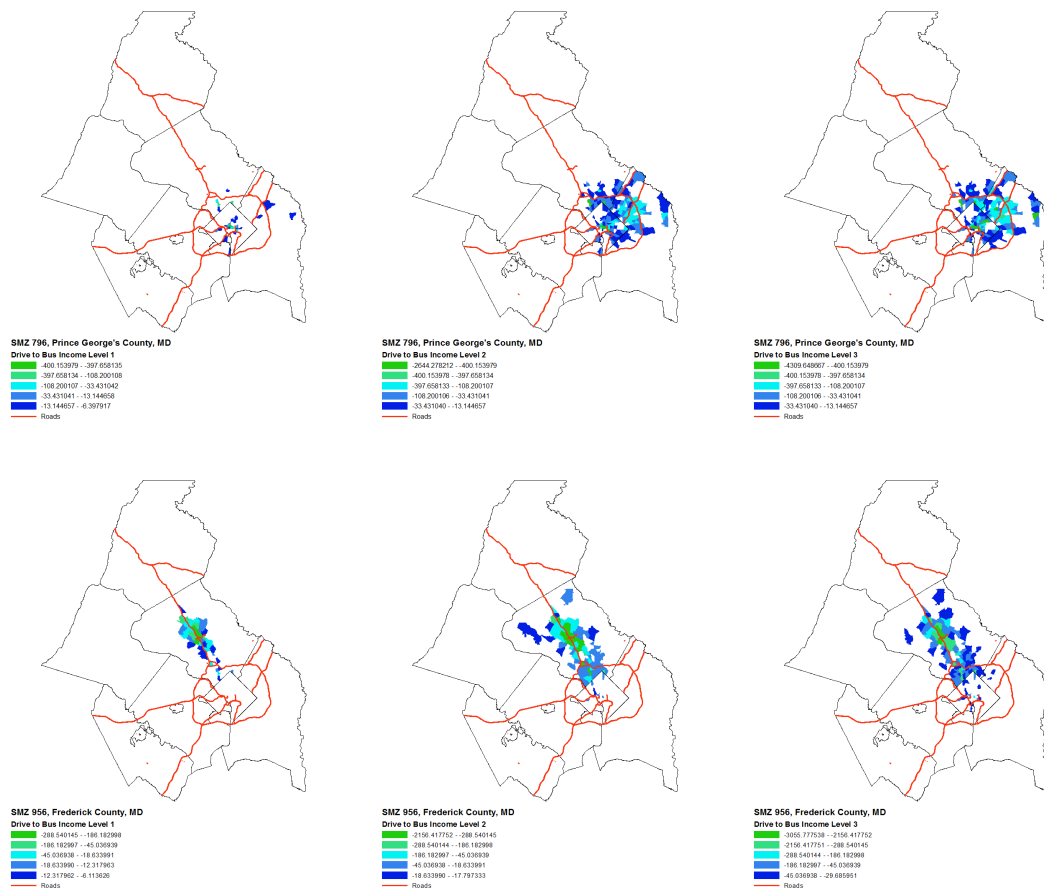


Figure B.11: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 796 (Lan-
 dover) and 956 (Frederick) in Maryland for Drive to Bus Transit.

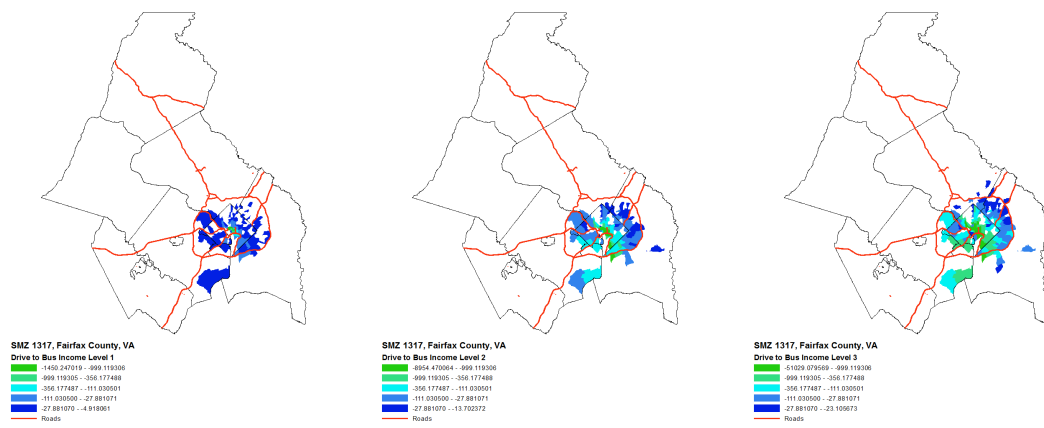


Figure B.12: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) in Virginia for Drive to Bus.

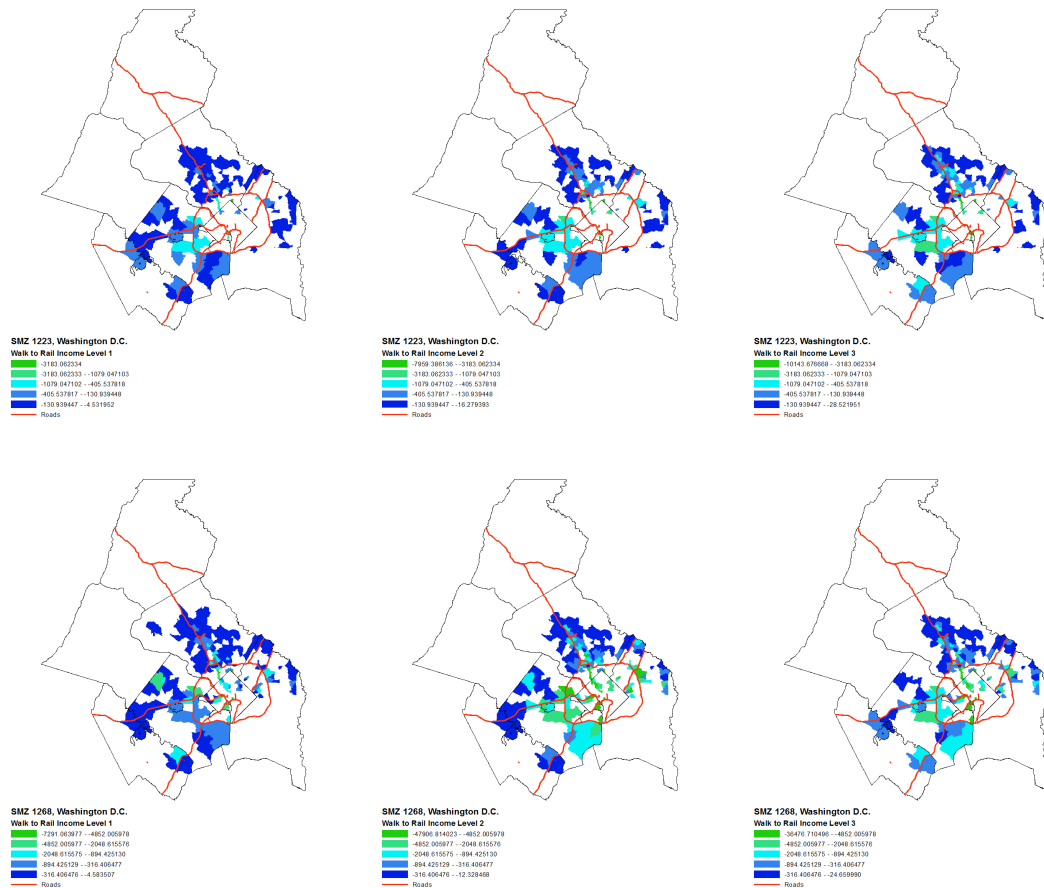


Figure B.13: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) and 1268 (Anacostia Metro) in Washington D.C. for Walk to Rail Transit.

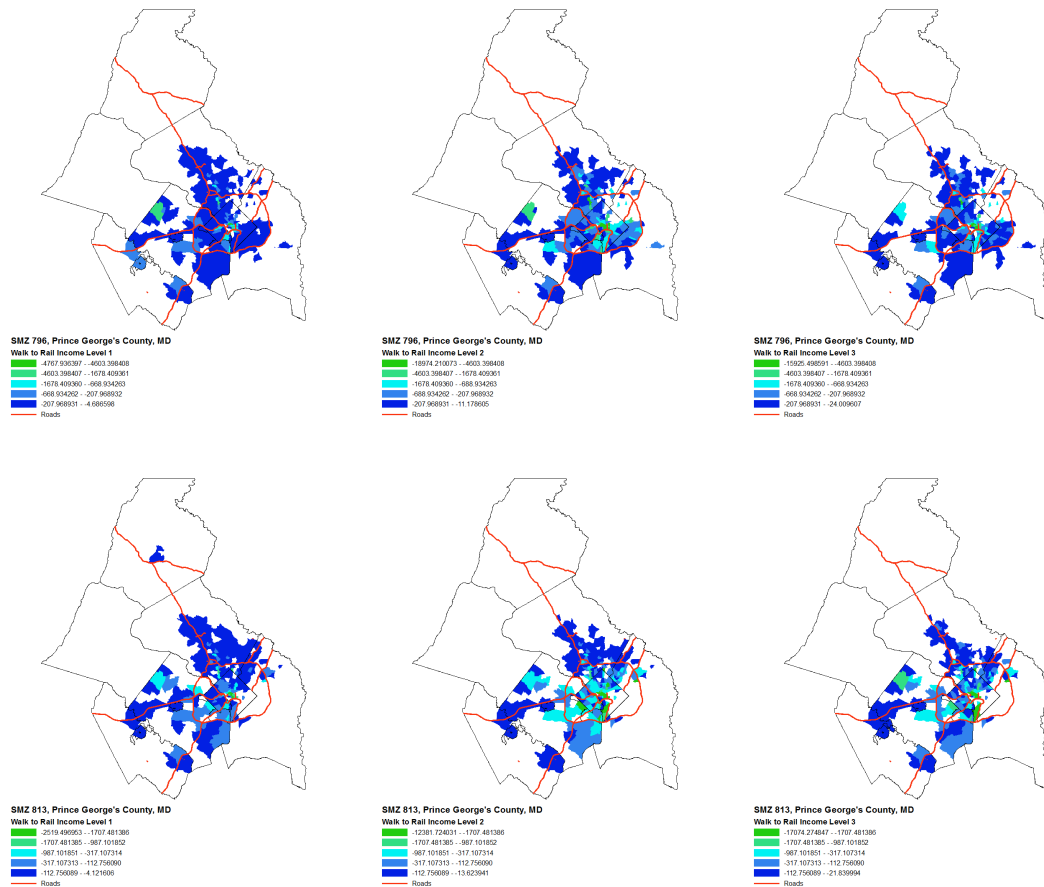


Figure B.14: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 796 (Lan-dover) and 813 (Suitland) in Maryland for Walk to Rail Transit.

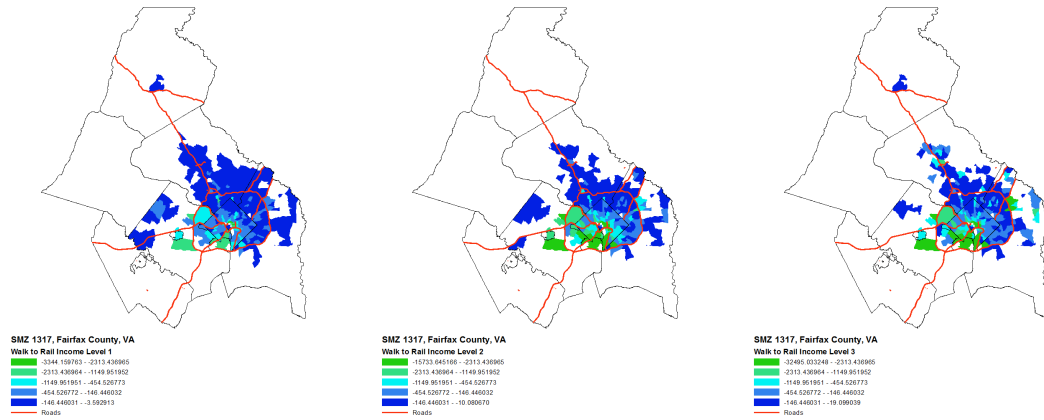


Figure B.15: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) in Virginia for Walk to Rail Transit.

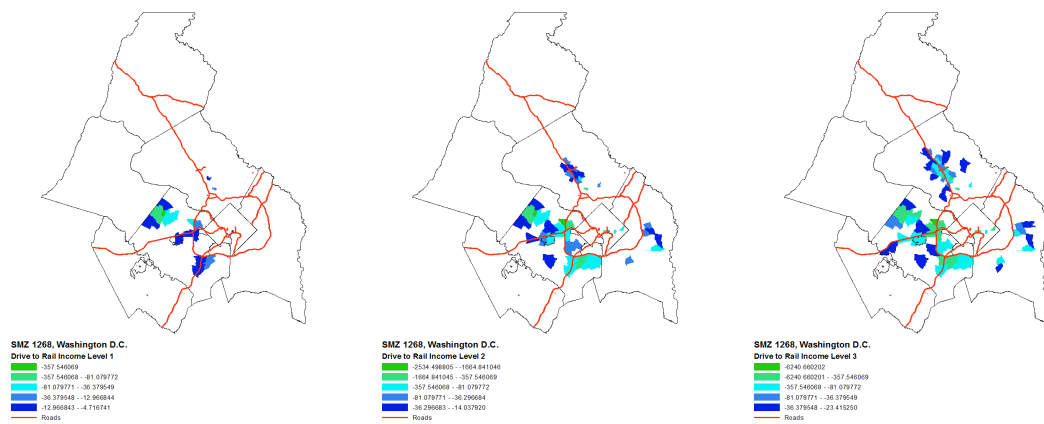


Figure B.16: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) in Washington D.C. for Drive to Rail Transit.

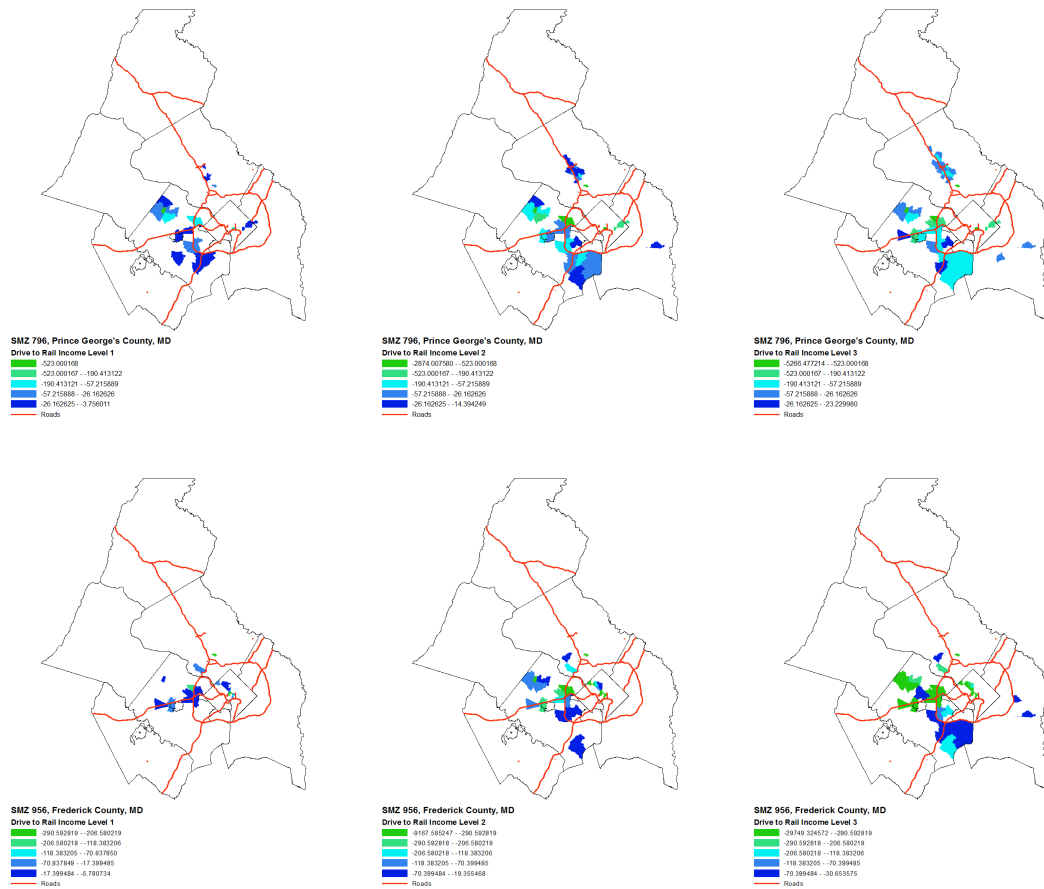


Figure B.17: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 796 (Lan-dover) and 956 (Frederick) in Maryland for Drive to Rail Transit.

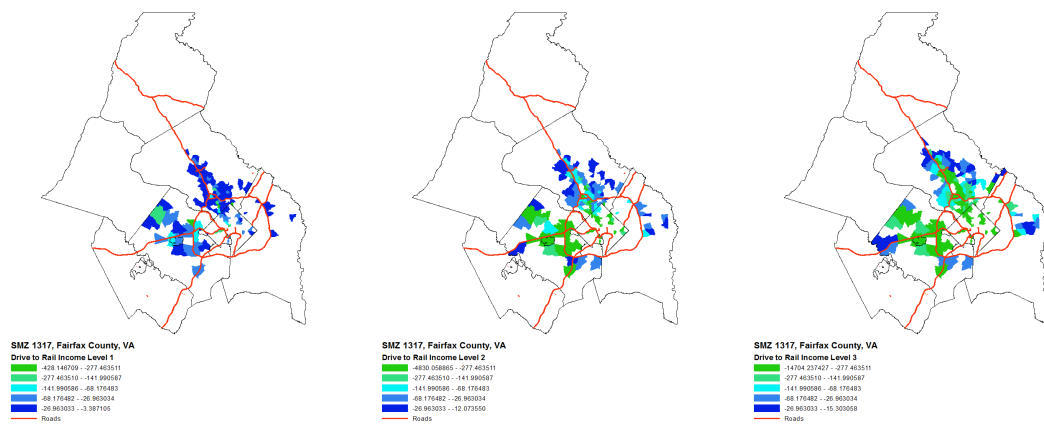


Figure B.18: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) in Virginia for Drive to Rail Transit.

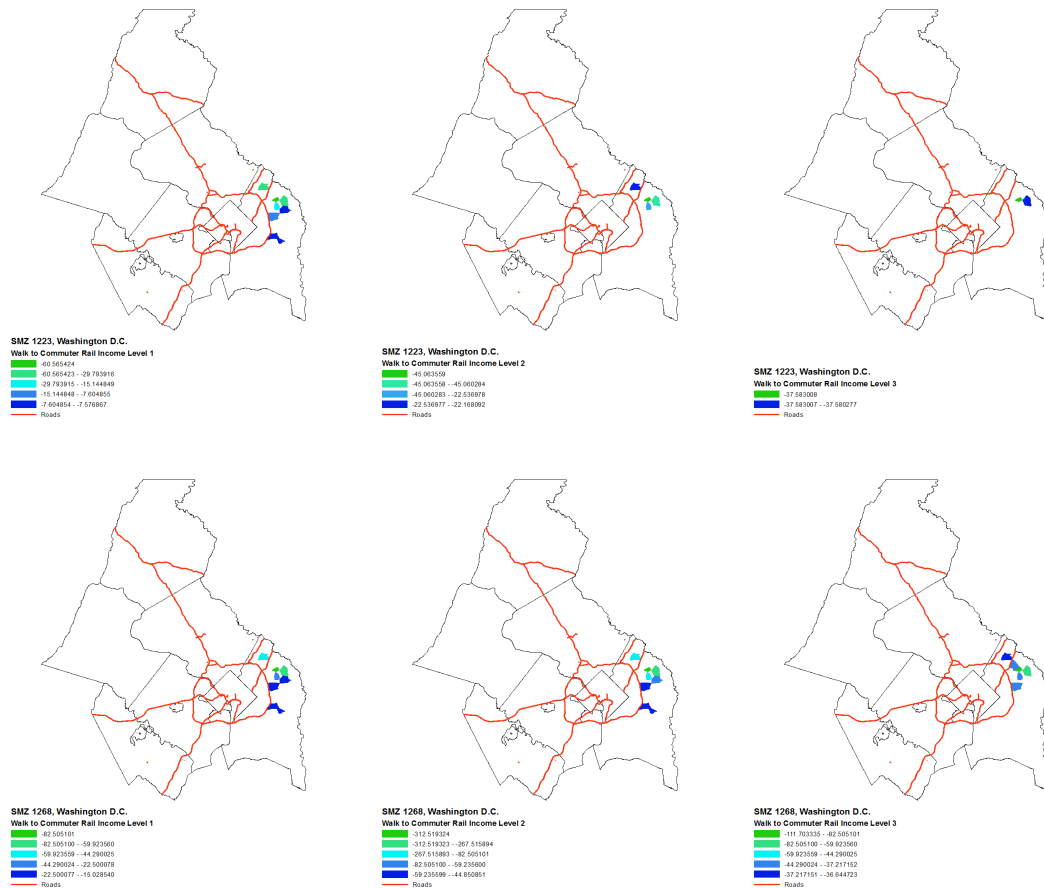


Figure B.19: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1223 (Rhode Island Metro) and 1268 (Anacostia Metro) in Washington D.C. for Walk to Commuter Rail Transit.

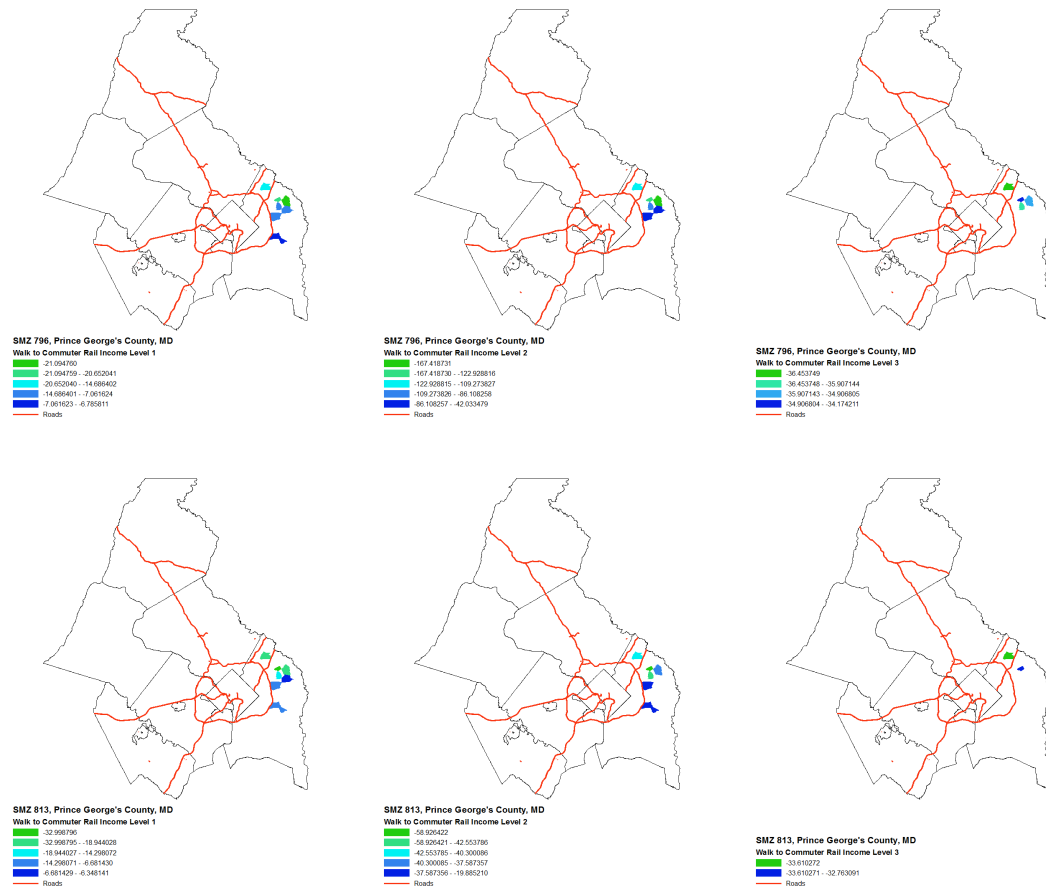


Figure B.20: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 796 (Lan-dover) and 813 (Suitland) in Maryland for Walk to Commuter Rail Transit.

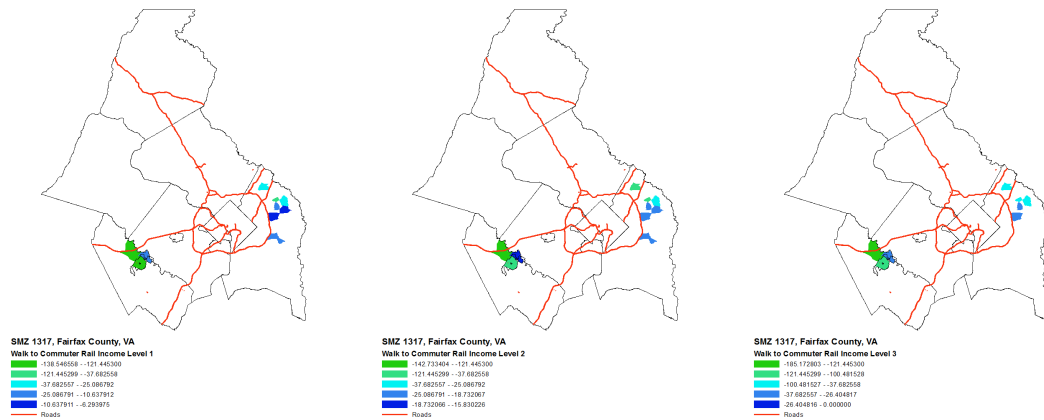


Figure B.21: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) in Virginia for Walk to Commuter Rail Transit.

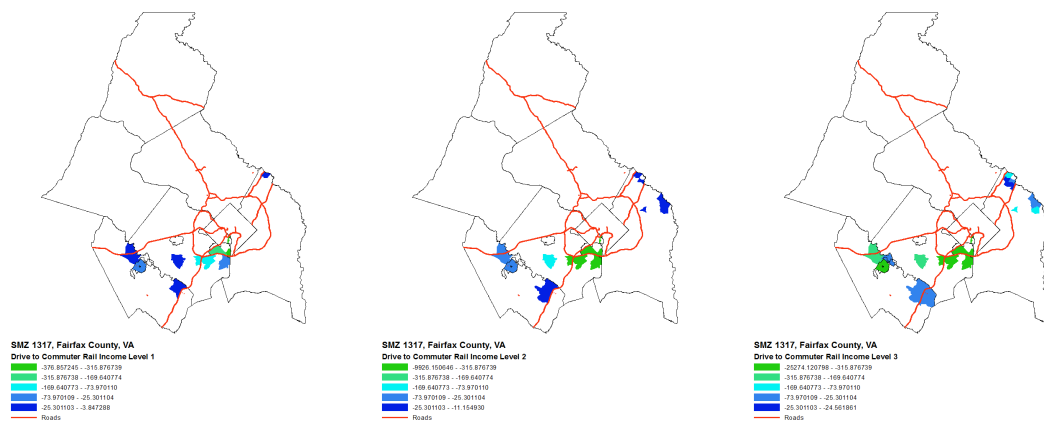


Figure B.22: Consumer Surplus for Income Levels 1, 2, and 3 for SMZ 1317 (Huntington) in Virginia for Drive to Commuter Rail Transit.

Bibliography

- American Public Transit Association. Apta 2000 transit fact book, 2000.
- E. Blumberg. En-genering effective planning: spatial mismatch, low income women, and transportation policy. *Journal of American Planning Association*, 70:269–281, 2004.
- E. Blumberg and M. Manville. Beyond the spatial mismatch: welfare recipients and transportation policy. *Journal of Planning Literature*, 19:182–205, Nov., 2004.
- K. Boesch. Ride for five: low-income transportation, pilot project final report, May, 2005.
- M. Criden. The stranded poor: recognizing the importance of public transportation for low income housheolds, 2008.
- G. de Jong, A. J. Daly, M. Pieters, and A. I. J. M. ver der Hoorn. The logsum as an evaluation measure: review of the literature and new results. *Transportation Research Part A*, 41:874–889, 2007.
- G. Giuliano. Low income, public transit, and mobility. *Transportation Research Board: Journal of the Transportation Research Board*, 1927:63–90, 2005.
- G. Giuliano, H. Hu, and K. Lee. The role of public transit in the mobility of low income households, May, 2001.
- H. Goldberg. State and county supported car ownership programs can help low-income families secure and keep jobs, 2001.
- D. C. Hodge. My fair share: equity issues in urban transportation. *Geography of Urban Transportation*, pages 359–375, 1995.
- E. Kalachek. In: Ghetto dwellers transportation and employment: Conference on transportation and poverty, 1968.
- J. Kasarda. Industrial restructuring and the changing locations of jobs. *America in the 1990s*, Volume I: Economic Trends:215–268, 1995.
- M. T. Lucas and C. F. Nicholson. Subsidized vehicle aquisition and earned income in the transition from welfare to work. *Transportation*, 30:483–501, 2003.
- E. Murakami and J. Young. Daily travle by persons with low income, Oct., 1997.
- U.S. Department of Transportation. National transit summeries and trends, 1998.
- P. Ong and E. Blumberg. Job access, commute and travel burden among welfare recipients. *Urban Studies*, 35:77–93, 1998.
- Richmond Area Metropolitan Planning Organization. Public transportation for the elderly, disabled, and low income: phase i - needs assessment report, Feb., 2006.

- J. Pucher and J. L. Renne. Socioeconomics of urban travel: evidence from the 2001 nhts. *Transportation Quarterly*, 57:49–77, 2003.
- J. Pucher, T. Evans, and J. Wenger. Socioeconomics of urban travel: evidence from the 1995 npts. *Transportation Quarterly*, 53:15–33, 1998.
- T. W. Sanchez. The connection between public transit and employment. *Journal of American Planning Association*, 65:284–296, 1999.
- T. W. Sanchez. The impact of public transportation on us metropolitan wage inequality. *Urban Studies*, 39:423–436, 2002.
- T. W. Sanchez. Poverty, policy, and public transportation. *Transportation Research Board: Transportation Research Part A*, 42:883–841, 2008.
- T. W. Sanchez, Q. Seng, and Z. Peng. Transit mobility, jobs access and low income labour participation in us metropolitan areas. *Urban Studies*, 47:1313–1331, 2004.
- Q. Shen. Location characteristics of inner-city neighborhoods and employment accessibility of low-wage workers. *Environment and Planning B*, 25:345–365, 1998.
- A. Tomer, E. Kneebone, R. Puentes, and A. Berube. Missed opportunities: Transit and jobs in metropolitan america, May, 2011.
- K. Train. *Discrete Choice Models with Simulation*. Cambridge University Press, Cambridge, 2003.
- M. Wachs and B. D. Taylor. Can transportation strategies help meet the welfare challenge? *Journal of American Planning Association*, 64:15–19, 1998.
- M. Waller. High cost or high opportunity cost? transportation and family economic success, Dec., 2005.