THE BUILT ENVIRONMENT, TRAVEL PATTERNS AND ENVIRONMENTAL BURDENS: A STUDY OF SIX NEIGHBORHOODS IN THE DETROIT, MICHIGAN REGION

By

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ABSTRACT

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The transportation industry is a significant contributor of greenhouse gasses. Within the transportation industry, light duty vehicles are the largest source of these emissions. Light duty vehicle emissions result from travel behavior and vehicle technology. Consequently there has been a plethora of studies that look into the travel patterns of residents living in various built environments. Research to date has also studied the various factors that impact travel patterns and travel behavior of residents with varying socio-economic characteristics. Linking travel patterns with pollutant emissions has not been as thoroughly researched. Emissions have been researched taking various built environment characteristics into consideration: these include congestion spots, highways, road conditions, and topography. Also, the effect of emissions on resident health has also been studied. However, research on the socio-economic characteristics of residents that affect *environmental burdens*, as measured by fuel consumption and vehicular emissions, is sorely lacking in the geography, planning and transportation literature. This study explores how the socio-economic composition of residents impacts travel patterns and environmental burdens within six neighborhoods in the Detroit, Michigan region.

The dataset for this study includes primary travel behavior data from a mail survey, and secondary data on vehicles from the Michigan Secretary of State and on specific gasoline consumption and vehicle emissions from the Environmental Protection Agency. Methods of analysis include Discriminant Analysis, K-Means Cluster Analysis and Regression Analyses to

derive the impacts of travel behavior and actual vehicle characteristics on travel patterns and environmental burdens. The six study neighborhoods were combined into three neighborhood typologies: Higher Density Urban (HDU), Higher Density Suburban (HDS) and Lower Density Suburban (LDS). This enabled the study to look at the effect of varying socio-economic characteristics of residents within each typology and how these contributed to environmental burdens.

Results of the study show that holding the built environment constant, the wealthier residents drive more and are responsible for higher levels of environmental burdens. This is the case even after taking into consideration that lower income residents have older, less technologically advanced vehicles that would typically consume more gas and emit higher levels of emissions. In addition, disinvestment can transform neighborhoods traditionally viewed as highly accessible (higher density, mixed land use and connected built environments) into neighborhoods that maintain the accessibility characteristics of low density, single-use zoned and disconnected suburbs. Despite this, it is evident that that environmental burdens associated with travel are shaped by class, with higher income earners disproportionately contributing to negative anthropogenic environmental impacts.

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Chapter I - Introduction

Suburbanization has dominated the primary settlement pattern and preference of many Americans since the mid twentieth century (Jackson, 1987). The impacts have been researched and debated upon extensively by scholars and professionals. Initial catalysts of the decentralization of American cities included the extensive highway system, a decline in real energy prices, subsidized infrastructure and land use and zoning practices (Baum and Snow, 2007b; Brown, Morris and Taylor, 2009; Harrison, 1974; Kopecky and Suen, 2010; McGrath, 2005; Vojnovic, 2000b). These factors, among others, have encouraged people to move further away from inner cities to less dense suburban areas, as the more affordable commutes became desirable and reasonable trade-off to ensuring a large home, a large lot, and privacy. The dependence on the automobile has been a cause and an effect of suburbanization. The transportation needs, patterns, and impacts of the developments have been researched under two general themes: travel patterns and behaviors, and the environmental concerns related to vehicular emissions (Ahn and Rakha, 2008; Bento et al, 2005; Brownstone and Golob, 2009; Cervero and Murakami, 2010; Crane and Crepeau, 1998; Ewing, 2001, 2010; Liu and Shen, 2011; Newman and Kenworthy, 1989, 1999; Vojnovic et al, forthcoming).

There have been a plethora of studies on commuting and travel patterns done at different levels of analysis with a general lack of smaller, individual and neighborhood levels of analyses to capture truer, more nuanced constraints and travel decisions (Holtzclaw, 2002; Horner and Murray, 2002; Lin and Long, 2008; Niedzielski, 2006). Existing studies have recognized the under-representation of research that allow for greater control of built environment characteristics and socio-economic conditions at the neighborhood scale. The result has been an increased effort to conduct studies at finer scales of analysis. Also, the attempt to capture both larger analysis levels (like the Census tract or the TAZ) with the smaller levels (like blocks and block groups) has been undertaken (Antipova et al, 2011). In studies of travel, the use of accessibility as a measure in neighborhood level analyses for travel behavior was adopted widely after Hansen's (1959) seminal piece on the topic (Ewing and Cervero, 2010; Liu and Shen, 2011; Zolnik, 2011).

There is also a notable absence of research on travel behavior focused on disadvantaged communities, i.e. neighborhoods experiencing disinvestment and decline. Within the existing built environment and travel behavior literature, the relationships between socio-economic conditions, the urban built environment and travel are recognized as underrepresented in research on urban planning, urban design, and urban and transportation geography (USDHHS, 2000; Day, 2003; 2006; Vojnovic, 2006; Vojnovic et al., 2006).

The importance of devoting more attention to research on the disadvantaged is also accentuated by a new understanding that the built environment and human behaviors, including travel, have a separate and distinct set of parameters that are influenced by not only class but also culture (Vojnovic et al., 2013). This lack of research on disadvantaged communities has led to the growing calls for more attention to be paid to the condition of lower income populations and their neighborhoods by both academic researchers and government agencies (Day, 2003; 2006; USDHHS, 2000; Vojnovic, 2006; Vojnovic et al, 2006).

In fact, it can be argued that while the number of disadvantaged has been on the rise, public officials, policymakers, and academics have been increasingly disinterested in the condition of marginalized neighborhoods. The concern for the poor and minority populations was a critical aspect of urban research and policy interest during the 1960s and 1970s, yet the focus on the disadvantaged has been diminishing since the 1980s (Slater, 2006; Podagrosi &

Vojnovic, 2008; Podagrosi et al., 2011). This is particularly evident in the research on the built environment, accessibility and travel behavior, an area of study that has almost exclusively focused on relatively dynamic and robust communities.

A similar under-representation of research is also evident in the literature on emissions. Emissions inventory and modeling have been addressed under the broader topic of the transportation industry as a key contributor to greenhouse gasses (GHGs) and climate change (Brown et al, 2008; Kromer et al, 2010; Lankao et al, 2009; Lutsey and Sperling, 2009; McCollum and Yang, 2005; Meyer, 2010; Moore et al, 2010; Plotkin, 1999; Schmalensee, 1998; Wheeler, 2008; Yang et al, 2009). The literature on the socio-economic dimension of gasoline consumption and pollutant emissions is sorely lacking. Studies on environmental burdens have been conducted at larger geographic scales, such as cities and metropolitan areas, and have also even been compared across countries. However, neighborhood level studies to understand the characteristics of those subgroups most responsible for environmental burdens, in terms of gasoline consumption and pollutant emissions, from travel within their immediate physical environment are notably absent. The existing literature has also not explored the relationships between physical and socio-economic conditions of neighborhoods and environmental burdens (gasoline consumption and pollutant emissions).

Within the context of the existing literature—and in an attempt to develop a better understanding of the effects of class on travel behavior, gasoline consumption and pollutant emissions at the neighborhood scale—this dissertation will focus on the intra-neighborhood analyses of three neighborhood typologies in the Detroit region. The six research sites are located within the SEMCOG (SouthEast Michigan Council of Governments) Region. This Region includes the counties of St. Clair, Livingston, Oakland, Macomb, Washtenaw, Wayne, and Monroe. The analyses will also consider the unique condition of disadvantaged communities—neighborhoods experiencing decline and disinvestment—with a focus on two lower eastside Detroit neighborhoods. The exploration of travel patterns, and resulting environmental burdens, including in communities experiencing severe disinvestment and decline, is a topic that has not been explored in the existing literature.

The research involves three neighborhood typologies: 1) higher density urban (HDU); 2) higher density suburban (HDS), and 3) lower density suburban (LDS). The higher density suburban and lower density suburban neighborhoods maintain similar socio economic characteristics, but they have very different urban built environments. These neighborhood typologies tend to be the traditional focus of travel behavior studies, exploring differences in travel between higher density, mixed land use, and highly connected neighborhoods and low density, generally single use, and disconnected neighborhoods. Beyond the built environment differences, these neighborhoods tend to be relatively robust, with regard to socio-economic composition.

The higher density urban neighborhoods are similar to the higher density suburban neighborhoods, in terms of urban form, but the socio economic characteristics of the urban neighborhoods are very different, and unique to travel behavior research. The Detroit urban neighborhoods are experiencing severe disinvestment and decline, despite the fact that they offer relatively high densities, a mix of land uses, and highly connected street networks.

Using built environment objective data and primary travel survey data, this research will focus on examining the impacts of socio-economic variables on travel, gasoline consumption, and pollutant emissions, specifically carbon monoxide emissions. The inclusion of the Detroit urban neighborhoods will also enable an assessment into the nature of travel behavior in neighborhoods characterized by urban disinvestment and decline, yet neighborhoods that still maintain higher urban densities, a concentrated land use mix, and a high degree of street connectivity. As already noted, within the existing travel behavior and urban form literature, this relationship between the built environment, class variables, and travel behavior is recognized as being underrepresented, and particularly in the context of exploring environmental burdens, here specifically gasoline consumption and pollutant emissions.

The Research Question

The primary research question then, is "Are there significant impacts of individual socio-economic characteristics on travel behavior and environmental burdens?" The main sub-question that would help answer the primary research question is: What socio-economic characteristics have a significant effect on travel patterns, gasoline consumption and vehicular emissions when holding the built environment constant?

Data Sources

Primary data, collected through mail-out surveys to six neighborhoods, has been used for this study. Secondary data from the U.S. Environmental Protection Agency (EPA) are also used to supplement the survey data in the analysis. These neighborhoods include two in inner city Detroit, and one each in the suburban areas of Ann Arbor, Bloomfield Hills, West Bloomfield and Birmingham. These neighborhoods were chosen to represent a mix of built environment, social, and economic factors.

Along with the survey data, emission estimates from the Environmental Protection Agency (EPA) have been used to get to best case scenarios for emissions specific to each vehicle owned by respondents to the survey. Key categories that the collected data variables would fall into include Demographic (age, sex, educational attainment, income), Travel Behavior (mode of travel, frequency of travel, and exact origin and destinations for travel to work, school, and optional purposes), and Vehicle Characteristics (make, model, year, miles driven, emissions, fuel economy).

Method of Analysis

Discriminant Analysis will help in identifying the factors that are significant in discriminating between the three neighborhood typologies: Higher Density Urban (HDU), Higher Density Suburban (HDS) and Lower Density Suburban (LDS). Cluster Analysis would help understand the groups that the data would form into within each typology. Lastly, using regression analysis, factors significantly affecting gasoline consumption and emissions will be derived across three neighborhood typologies. All methodologies are discussed in greater detail in Chapter V.

General Hypothesis

It is hypothesized that higher income residents will consume higher amounts of gasoline due to their larger vehicles and stronger engine horsepower. Even though they are expected to have newer vehicles and thus better fuel economy, their reliance on the private vehicle for transportation and the distance that they travel in larger vehicles would overpower the positive impacts of the higher fuel economy and result in higher amounts of gasoline consumption. Lower income residents on the other hand are more dependent on public transportation and walking and so will consume less gasoline and emit fewer emissions. When considering only the built environment (density, land use mix and connectivity), low density suburban residents are expected to consume more gasoline due to the longer commutes from their suburban homes to all trip destinations, while higher density suburban residents and inner city residents are expected to consume less gasoline due to the high connectivity, density and land use mix of their built environment.

Main Contribution and Implications

In essence, this study will analyze the nature of environmental burdens across the six neighborhoods in the Detroit metropolitan region. These results have policy implications for planners and transportation professionals. This is especially important at a time when the State is looking at three legislations that either propose to increase gas taxes or State sales taxes to help pay for road maintenance and repair (Eggert, 2013). Also, this study would be useful to the issue of the Gas Guzzler Tax (1978) that is a tax on manufacturers for those vehicles sold that do not meet minimum fuel efficiency standards. This tax however, applies only to light duty vehicles and exempts SUVs, minivans, and pick-up trucks. Further, this study would lend more detail and uncover nuances inherent in research on travel behavior and emissions modeling. As such the research on this topic lacks insight into the socio-economic impacts on environmental burdens.

This dissertation is divided into seven chapters. The next chapter (Chapter II) is the literature review, which will discuss research done on suburbanization to first get at the causes and effects of the different urban built environments. Then travel patterns will be discussed to get at research done on vehicle miles traveled (VMT) and travel behavior of people. Lastly, the literature review will discuss emissions in an effort to show the disconnect between a physical phenomenon (emissions/pollutants) and its very anthropogenic source.

Chapter III is a brief overview of Detroit and journey through its growth years and the subsequent decline. It is important to know where this City has been and what were the factors in its decline to truly understand its uniqueness and the difference from other large declining cities. Chapter IV goes into the details of the neighborhoods included in this study. The reasoning behind the various neighborhoods selected for this study and an objective assessment of the physical character of these neighborhoods is laid out to help the reader get a complete look at built environment characteristics.

Chapter V is on the Research Hypotheses, Data and Methodology. This chapter discusses the data gathered, including the primary and secondary data used in the study. This study uses a database that is very detailed, both in scale and scope, which is a big part of the unique contribution this study offers to the existing literature. The chapter also lays out the research hypotheses to be tested and the analyses conducted. Apart from the usual regressions used to test the hypotheses, the study has used a blend of quantitative and qualitative assessments to tease out the differences in travel patterns and environmental burdens.

The sixth chapter discusses the results of the analyses. Along with the results of the hypotheses tests conducted, I present a complete picture of the differences in travel behavior and environmental burdens across the neighborhoods and within similar neighborhood types. Following the quantitative analyses results, nuances are extracted with the use of qualitative assessments that drive the main argument of this study further. This chapter ends with a concluding commentary on all the results and what they mean when we look at the whole issue of the socio economics and the built environment impacts of travel behavior and environmental burdens in a combined manner. The seventh chapter forms the conclusion of the entire dissertation, ties everything together and presents a complete package – a holistic view of the travel behavior and environmental burdens research conducted for this dissertation.

Chapter II - Literature Review

Suburbanization

Suburbanization, best understood as a process of residential and commercial dispersion from the central city to outer, fringe areas, has been researched for decades. It is so engrained in the American culture and way of life that it has been labeled as the "manifestation of the fundamental characteristic of American society" (Jackson, 1987: Pg 4). Shay and Khattak (2012) point out that while the urban population has grown by 80% between 1960 and 2000, the urbanized land area has grown by 130%. While studies date the beginnings of suburbanization to the 18^{th} century (Lewis, 2002; Walker & Lewis, 2001), most of the literature recognizes increasing levels of suburbanization as occurring from the mid 1900s and onwards, a result of increased economic prosperity and rapid population growth. For instance, the 1950s were marked by mortgage issuance policy initiatives that encouraged the purchase of large single-family homes in the suburbs. This decade was also marked by the construction of the Interstate highway system that further facilitated the rapid move outward of the urban population.

Most of the studies also attribute suburbanization to be an effect of different transportation modes. For example, Warner (2004) shows how the streetcar led to suburbanization in Boston in the late 1800s. Similarly, the streetcar system had been a significant force in the growth of the twin cities of Minneapolis and St Paul (Adams and VanDrasek, 1993). Thus, even before the private automobile, other transportation modes were facilitating early American urban decentralization (Xie and Levinson, 2010).

Then came the Interstate Highway System. Baum-Snow (2007b) studied the effects of highway construction on central city and Metropolitan Statistical Area population density for all large MSAs in the country between 1950 and 1990. He estimated that with every addition of a highway ray, i.e. a highway that connects the CBD to a region outside, population density falls by about 1%. In terms of the population itself, each additional ray of highway causes a 9% decline in central city population. Baum-Snow also estimated that highway construction accounts for a third of the population density difference between the metro area as a whole and the central cities between 1950 and 1990. Had the interstate highway system not been built, the central city population, between the years 1950 and 1990, would have increased by 8%, instead of declining by 17% (Baum-Snow, 2007b).

Urban highways that existed before the Interstate highway system were designed to flow with the urban fabric and increase the speed of vehicles (transit and private auto) with the least possible disruption. With the building of the Interstate Highway system, and the shift of transportation control and funding from local to state and federal agencies, the focus on the fabric of the neighborhoods lost priority and the primary focus became simply speed, as that was the sign of being progressive (Brown, Morris, and Taylor, 2009).

Kopecky and Suen (2010) assert that rising incomes and falling automobile prices were the key drivers of suburbanization. Furthermore, into the second half of the 20th century, city centers became increasingly marked by crime, lack of educational opportunities, and high poverty rates, all of which became a strong ‘push" factor for residents that could afford the suburbs (Mieszkowski & Mills, 1993). This, in turn, overburdened the central city capacity to provide public services, leading to higher taxes and lower quality of services, further facilitating suburbanization.

While there are various causes that lead to suburbanization, government policies are seen as an important variable driving decentralization. These policies relate to building transportation network infrastructure, allowing fragmentation of metropolitan areas, and handing over political control to local governments that are under pressure from their majority constituents to keep certain ethnic or income groups out of their jurisdictions. The under-pricing of infrastructure by local governments has led to an oversupply and overconsumption of these services by residents (Vojnovic, 2000b). Cities have continually subsidized services such as road infrastructure, water and sewer, and residents have not had to pay the true costs of these amenities. Overconsumption, in turn, has led to further decentralization as people pay less to move to further places and also purchase houses on large lots. On a similar note, McGrath (2005) asserts that had the costs of private transportation been more reflective of actual costs, U.S. metro areas would not be that spread out; the higher costs would have resulted in more compact urban regions.

Harrison (1974) maintains that institutional inflexibility furthers the financial difficulties of central cities. Failure of policy is the main cause for the condition that inner cities are in now and most attention needs to be given to these policies if any remedy is to be sought. Similarly, Adams et al (1996) show that a strong central city benefits the metro area as a whole and policies and institutional arrangements (such as tax base sharing, metro-wide economic development, and disbursement of low income families through mixed income neighborhoods) should be in place to discourage central city decline.

In essence, various theories and hypotheses explaining growth in central cities and their suburbs have evolved, ranging from "push" to "pull" factors. The "push" factor suggests that growth in suburbs is the result of the flight of the population from central cities to avoid crime, congestion, taxes, poverty and social and economic problems (Mieszkowski and Mills 1993). The “pull” factor suggests that the search for better amenities, larger housing, and a better quality of life by residents, and the search for a larger and more affluent customer base by businesses, drives the growth in suburban locations compared to central cities (Leichenko, 2001). Whatever the actual impetus may be for particular families, households, or businesses to suburbanize, the one clear pattern in the process is that urban decentralization has been rapidly increasing.

Effects of Suburbanization

With the decentralization of cities, new social costs emerged across the American urban landscape. One social cost became evident with the loss of community and street life (Jacobs, 1961). With suburbanization, increasing segregation also crystallized (Darden & Kamel, 2000). Residential segregation by race is persistent in many urban areas that have been vacated by the white, moderate income population that moved into suburbs. Most often, the African American population is the one that has been associated with being segregated, that is, living in enclaves in the inner city with a majority percentage of residents of the same race. Segregation affects a variety of outcomes that deal with health, education, income, and occupation. Ananat (2011) refers to segregation as being the main cause of economic inequality. She finds that there is greater inequality and higher poverty rates within the black, segregated population, while lower inequality and poverty rates exist among the white population.

Kain’s (1968) seminal piece on spatial mismatch has received generous attention in the academic literature on the topic. Together with the Kerner Commission’s Report (1968), these works stress the critical nature of accessibility to jobs, especially for the African American population. The general explanation for the spatial mismatch theory is that African-American employment is lower in suburbs because the job location is far from their residential location, which is usually in the inner cities. More importantly, many African-Americans do not have automobiles and there is a lack of robust public transit systems connecting the urban core to the suburbs, which results in higher costs (monetary and/or temporal) for them to reach jobs in the suburbs. The Kerner Commission's Report on the riots in Los Angeles in the 1960s stressed the access problems for the African American residents and the resultant unemployment as being the main underlying causes for the rioting. Cohn and Fosselt (1998) put forth a further dimension to the issue of spatial "mismatch" by proposing that minority urban residents hesitate to take up jobs in areas where they perceive discrimination against them, the suburban jurisdictions.

While numerous dimensions of inequality have emerged from resulting suburbanization patterns, education has been a particular point of concern. Baum-Snow and Lutz (2011) conducted a study of 92 large urban school districts and found that whites made up a disproportionate section of movers, as the authors show that the white population declined by 13 percent and black population increased by 54 percent between 1960 and 1990. With the exodus from the inner city, came deteriorating properties, lower taxes, and lower budgets for urban school jurisdiction. Card and Krueger (1996) assert that an increase in residential segregation increases beneficial school resources for the white community, while lowering those for the black community. The residential move to suburban neighborhoods, along with the move of upper class white students to suburban schools, has left inner city schools with a race-homogenous student population (African-American students) and funded by a class-homogenous resident population (lower-income African-American urban residents). In essence, school segregation has been an important aspect of suburbanization that has had a substantial effect on the racial fabric of central cities.

In his book on Urban Economic Development, Harrison (1974) shows that about four thousand to nine thousand jobs were in suburban Detroit in 1952, which African-Americans were unable to take up due to residential segregation. These suburbanizing jobs required low skills while those left in the central city required higher skills. Thus African-Americans lost out on the jobs left in the central city to the suburbanites who were competing for and were better suited to those central city jobs. The author also talks about the "exploitation hypothesis," which states that the benefits that a central city gives its non-resident population are borne by taxes paid by the resident population. Workers coming in to the central city use parks, roads, and entertainment venues which all need increased public services. The costs of these services are borne by the poor residents who live in the region alone. Even though some have argued that the problem with central city's poverty rates is one of the main forces behind the flight of the white population to the suburbs, and not race per se, Harrison believes that there is something beyond financial resources and economic systems in force in these decentralization patterns.

Recent research has shown that segregation is decreasing, even though it is a slow process (Clark and Blue 2004; Frey 2000; Clark 2007). The main point is that with increasing incomes, the Black population has been able to move to the suburbs and live in integrated neighborhoods. Blacks in central cities are still segregated from whites (Clark and Blue, 2004). Also, the influx of minorities as immigrants, who choose to move directly to suburbs to settle, has been influencing segregation in U.S. metropolitan areas. Although Clark (2007) shows this apparent integration as being disproportionately visible in the suburbs, and less so in central cities, Fischer (2008) shows that Black segregation has declined mainly in the inner cities (at least for the Northeast and Midwest Regions). In addition, Fischer stresses that between 1980 and 2000, increases in Black suburbanization has been met with segregation patterns within the suburbs. In those areas where a large portion of Blacks moved to suburban locations, the threshold of tolerance of whites already living in such locations was breached; whites started moving out, the neighborhood became increasingly black, and this resulted in segregated neighborhoods. As long as Blacks remained the minority and did not tip the neighborhood balance, their movement into suburban neighborhoods was welcomed, or perhaps more appropriately, tolerated.

Through the long standing history of research and inquiry on suburbanization, it is clear that government policies have been at the crux of the urban decentralization experienced by American cities. The result of these urban development processes have been evident in intended and unintended consequences. While quality of life factors, personal choices, and prosperity have been achieved for those who could afford suburban lifestyles, many argue that segregation, blight, economic drain and environmental degradation have also been resulting outcomes that have produced extensive costs to American urban regions. Moving on from this, we can now look at the various and contrasting environments, patterns and behavioral elements that get adopted by residents living in different areas: inner-city and suburban, and how these impact travel patterns and behavior.

Travel Patterns/Behavior

Over the last several decades, there have been numerous studies focusing on the various dimensions of travel patterns and vehicle miles traveled (henceforth referred to as VMT) within North American cities. In essence, studies try to determine what factors impact VMT and what policy implications should stem from such impacts. Some studies focus on built environment designs and conditions that influence travel patterns (Bento et al, 2005; Brownstone & Golob, 2009; Vojnovic, 2006; Cervero & Murakami, 2010; Dunphy & Fisher, 1996; Kockelman, 1996; Schimek, 1996; Gordon & Richardson; Newman & Kenworthy, 1989, 1999; Cervero & Radisch, 1996; Krizek, 2003; Lin & Long, 2008) while others attribute varying travel patterns to personal and household characteristics (Weber & Kwan, 2003; Crane & Crepeau, 1998; Rodriguez et al, 2006; Vojnovic et al, 2013; forthcoming). Some of the studies have analyzed vehicle ownership and travel patterns of residents (Goetzke and Weinberger, 2012; Holtzclaw, 2002; Shay and Khattak, 2012; Taylor and Mauch, 1998) while others have focused on emissions modeling (Lindsey et al, 2007; McCollum and Yang, 2009; Stone et al, 2007). The following section of this chapter will explore the nature of relationships established between travel behavior, gasoline consumption, pollutant emissions, socio-economic conditions, and the urban built environment.

Another set of studies focus on issues of inequality between residents of different density areas, different races, built up levels of areas (urban/suburban) and distance and time spent in travel for a typical resident (Pucher & Renne, 2003; Blumenberg, 2004; Sultana, 2002). Research on factors that impact vehicle ownership and miles of travel has typically dealt with two broad, overlapping aspects, neighborhood characteristics and personal/household socioeconomic characteristics.

Built Environment and Travel Demand

Neighborhood physical and design characteristics and their impact on vehicle ownership and VMT have been an important aspect of travel behavior research. Within this line of research, density as a built environment characteristic, and its impact on travel, has been the focus of many works (Bhat and Guo, 2007; Cao et al, 2007; Holtzclaw et al, 2002; Kahn, 2006; Su, 2010; Cervero and Murakami, 2010). The research shows that the greater the density, the less vehicles owned and fewer miles traveled by private automobile, as accessibility to different destinations is improved, and public transit systems (if present) would carry much of the travel load. In addition, an increased ownership of light duty trucks has been associated with a higher number of vehicles per household, a higher number of household members, and with suburban, low density, residential neighborhoods (Potoglou 2008; Cao et al 2006; Zhao and Kockelman 2000). Bento et al (2005) used the 1990 NPTS data and studied the impact of urban form and transit availability on Vehicle Miles Traveled (VMT) and commute mode choice. They find that urban sprawl measures and public transit supply have marginal effects on travel demand, however, taken together (i.e. simultaneously), these measures have a considerable impact on travel. In essence, they caution against policy measures that only focus on one variable (like density) to influence VMT. There are a varied number of measures of urban form (like population and employment density, road density, jobs-housing balance, streetscape texture, population centrality and availability of public transit) that work together to affect t ravel behavior. Policies should be cognizant of this complexity in the relationship between urban built environment characteristics and travel.

This line of thought has been the bases for many studies that look at commute times and distances as an effect of suburbanization. The general idea is that commute times and distances have increased in the late 20th century as a result of the sprawling patterns of residential locations (Rossetti and Eversole, 1993; McCuckin and Srinivasan, 2003; Reschovsky, 2004). The increasing VMT is related to increasing local and global pollution, energy consumption, open space consumption and that of other scarce resources (Cervero & Murakami, 2010). Curbing this trend, compact development could reduce vehicle miles traveled in the next four decades by about 17% (Bartholomew and Ewing, 2009). Shay and Khattak (2012) find that characteristics of neighborhoods that encourage walkability and non-motorized forms of travel translate into fewer cars per household and a greater propensity to use those non-motorized forms of travel. However, these neighborhood characteristics would entail a greater number of trips due to the shorter trip lengths.

Other studies have found more ambiguous results between the association of suburbanization and auto ownership, commutes times and commute distances. For example, Kain (1967) implied that the relationship between density and car ownership is such that both influence each other and that there is no unidirectional influence. Kahn (2006) found that low density suburbs had longer commute distances to work but lower commute times, due to the speed of travel, when compared to higher density suburbs. Ewing (2002; 2003a) found that there was no clear indication that commute times had increased for suburban residents He attributed this to the fact that although an imbalance between jobs and housing increased travel distances to work, the decentralization process reduced commute times in the sense that highway travel was faster and people could cover longer distances in less time.

Zolnik (2011), on the other hand, found that higher residential density, the degree of centering and accessibility (street system) had a small, but significant negative impact on commuting to work distances and times. Similarly, Liu and Shen (2011) find that amongst the urban form characteristics, accessibility is the only characteristic that has a significant negative impact on annual household VMT. Holtzclaw (2002), in a study that modeled vehicles per household and VMT per household as they would relate to residential densities, concluded that increased densities were associated with lower VMT.

The complex relationships between different neighborhood characteristics and travel demand complicate the issue further. For instance, Cervero and Murakami (2010) studied some 370 urbanized areas throughout the country to determine the effects of the built environment on VMT. They find that although there is a direct, strong, negative association between population density and VMT per capita of -.604 (indicating that a doubling of population density would reduce VMT by 60%), there are also other positive, indirect associations. Road density, urbanized area size and retail accessibility are three factors that yield in increases in VMT. Their combined positive association reduces the net negative association between population density and VMT per capita to -.381, indicating that a doubling of population density would reduce VMT by 38%.

Similarly Su (2010) studies 85 urban areas over a 20 year period (from 1982 to 2003) across the nation and finds that road density and urban spatial size have a positive and significant impact on travel demand, while population density and congestion have a negative and significant impact on travel demand. Vojnovic et al (2006) studied urban form and public health in Michigan and stressed that even though increased densities will not ensure that people will go shopping at the nearest store or eat out at the nearest restaurant, the increased densities will shorten distances between destinations and give residents the “choice” to use non-motorized modes of travel, and over the long run, relieve the dependence on the automobile. In 2010, Ewing and Cervero did a review of previous research on the built environment and travel patterns and found that VMT was most strongly associated with destination accessibility, followed by distance to downtown (which they associated with density and accessibility), and then design characteristics; with the three maintain the strongest association with VMT.

In sum, a majority of the existing research agrees that the built environment does have an influence on travel patterns. Density has a positive association with number of trips, which have a greater likelihood to be by non-motorized means, but a negative association with the distance of travel, vehicle ownership, and size of vehicle. Similarly, accessibility and land-use mix have been shown to have a positive association with alternatives (including non-motorized) travel modes and a negative association with travel distances (VMT).

Socioeconomic Characteristics and Travel Behavior

Socio economic characteristics relate to travel behavior based on cultural and social norms and class factors. Researchers have identified endogenous and contextual effects (termed as “social spillover” effects) on auto ownership. These effects translate into the notion that an individual’s actions and behavior change with the attitudes and behaviors of his/her peers (Goetzke and Weinberger, 2012; Manski 2000). Consequently policies aiming to reduce VMT through car ownership should recognize that there is a self-reinforcing social multiplier that comes into play when goals for reduced car ownership are formed (Chen et al, 2008; Weinberger and Goetzke, 2010; Weinberger et al, 2009; Shoup, 2005).

While neighborhood physical characteristics are important, some researchers believe that pushing for higher densities would have a negligible impact on VMT due to a higher influence of individual driver characteristics (Brownstone & Golob, 2009). Weber & Kwan (2003) have worked on multiple levels to gain an understanding and differentiate between neighborhood/location effects and personal/household characteristics when analyzing time-accessibility in Portland, Oregon. They conclude that it is not the location characteristic but the individual characteristic that has an influence on travel and accessibility, and that further studies on the topic should approach it from an individualistic perspective. Similar findings were presented by Crane & Crepeau (1998) and Rodriguez et al (2006).

The sensitivity of travel patterns have also been linked to socio-economic traits in more recent research. Paulley et al (2006) have shown that increasing incomes are significantly related to increased auto ownership and VMT. Ewing and Cervero (2001) find that some aspects of travel, such as trip generation rates, are more sensitive to socio economic characteristics, while mode choice is affected more by the local built environment.

Several researchers have also shown an increasing effect of socio demographic characteristics of the minority and disadvantaged population subgroups (low income, women and the elderly) on mode choice and VMT (Helling, 2000; McDonald, 2005; Cao et al, 2010; Kim and Ulfarsson, 2004; Matthies et al, 2002). As different scales give different results to research on travel behavior (Vojnovic, 2006; Sultana, 2002), different ethnic and population groups would also have different impacts on VMT (Pucher & Renne, 2003; Blumenberg, 2004). These studies suggest that the marginalized populations (females, racial minorities, poor) depend on travel via private automobile to a great extent and largely because of limited alternative travel options. Even though this may be a burden on their finances, the lack of effective public transit leaves lower-income sub-groups with no other choice than to drive to be able to reach their destinations, including employment. Running daily errands and necessity shopping can be handled with ease when driving around in a private vehicle. Trip chaining, a concept that suggests that people might get to multiple destinations in one trip (for example, going to the grocery store, drycleaners and the post office on your way home from work) is favored by women travelers, especially as this seems a more practical use of time and resources. However, trip chaining also reduces the attractiveness of alternative transportation modes to the private automobile, and especially public transit (Taylor and Mauch, 1998).

The subject of 'self-selection' has been explored in many studies, however, some researchers feel that self-selection is manifest in the socio-demographic characteristics of the residents and when these are taken into control, self-selection is also controlled (Shay and Khattak, 2012). The caveat being that the built environment of these neighborhoods allows for that choice (self-selection) to be exercised and similar to controlling for socio-demographic characteristics, controlling for the built environment deals effectively with this issue.

Glaeser et al (2008) contend that the poor live in inner cities mainly because they need to be closer to public transportation. Public transit plays a major role in the initial tendency of the poor to locate in inner cities as they need to be closer to work destinations. Once they settle in these inner city areas, problems due to the concentration of the poor in small areas exacerbate other social and financial problems that prove to be the impetus for others to move out. The main point in their national study of MSAs being that the housing market alone is not responsible for the sorting of population by class in the suburbanization process, but that transportation mode choice plays a critical role in explaining income sorting (Glaeser et al, 2008). On a similar note, Vojnovic et al (2007), in their study on the built environment and its effects on physical activity and health impacts state that eradicating racial and class discrimination is critical to the success of policies that encourage compact development. In turn, the compact developments help in increasing physical activity and can promote positive health outcomes by reducing the dependence on the automobile.

Konduri et al (2011) in their study on the relationship between vehicle type choice and trip length, found that the former influenced the latter. They found that the use of vans as the mode of travel was associated with longer distances, while the use of a SUV was associated with shorter distances, even though the SUV seemed to be the first choice for a household with more than one vehicle in its fleet. The car, as the vehicle of choice, was used for longer trips than trips by SUV or pickup truck, but slightly shorter trips than those undertaken with a van. The authors caution against policies that have the intent of encouraging the use of smaller vehicles (specifically the car), as people exercise trade-offs in their use of vehicles and might use their smaller vehicles for longer distances, which would negate the positive effect of the policy. Although not specifically related to any socio-economic characteristics, this is a derivative of it as it is related to actions and choices by people about the types of vehicles they buy and travel in for different trips.

Liu and Shen (2011) also examine the impacts of urban form and socio economic characteristics in their study on VMT, energy consumption and carbon dioxide emissions. They find that although urban form is only indirectly associated with VMT, socio-economic characteristics, such as number of vehicles owned, income, gender, race age and family structure have significant impacts on VMT and energy consumption.

Built environment and socioeconomic factors and travel behavior

Incorporating the built environment and socio economic characteristics, Vojnovic et al (2013) study the impacts on travel behavior and health of residents in six Lansing area, Michigan, neighborhoods. Their results show that neighborhoods in urban and inner suburban areas had a greater mix of land uses and higher connectivity characteristics. Residents of outer suburban areas were far more reliant on the automobile than those in inner suburban and urban neighborhoods. Even so, socio economic conditions dictated the extent to which residents would use non-motorized/motorized modes of travel. The lack of stores with healthy food options in the declining urban cores and the proliferation of these in the outer, wealthy suburban areas made average distances to these stores shorter for higher-income suburban residents and longer for lower-income urban residents, indicating that neighborhood investment was a critical factor in deriving distances to destinations and affecting travel patterns. The built environment characteristics facilitated walkability and lower levels of reliance on the automobile, however, socio economic factors turned out to be the main dictator of travel behavior.

A review of research on the various associations with VMT by Ewing and Cervero in 2001 showed that although mode of travel choice depended on both the built environment and socioeconomic characteristics, trip frequency was primarily associated with socioeconomic characteristics and secondarily with the built environment. In contrast, trip length was primarily associated with the built environment and secondarily with socioeconomic characteristics. This is understandable, as areas that are denser, more accessible and have mixed uses, would require shorter trip lengths to get to final destination points. However, due to the short trip characteristic, people are willing to get out more often to get to their destinations, especially since those destinations are closer, resulting in a larger number of trips. These shorter trips, however, have a greater likelihood of being by non-motorized means.

Grengs (2010) takes the notion of spatial mismatch further, agreeing with researchers such as Blumenberg and Manville (2004), and shows that it is not the case of distance between job availability and prospective employees' residence, but that the lack of a private vehicle to get to the available jobs is what is hindering greater employment levels for poor African Americans, at least in the Detroit metropolitan context. In his study, he used data from the 2000 Census Transportation Planning Package (CTPP), 2000 Census, and data from SEMCOG. He shows that the inner city of Detroit is where accessibility to low-wage jobs is the poorest, compared to the rest of the metropolitan region. That said, there are considerable variations in the different neighborhoods in the inner city that relate to accessibility, indicating that not all neighborhoods face the problem of spatial mismatch.

However, on closer investigation, he shows that since Detroit's public transit is so inferior compared to other large metropolitan regions, that accessibility is more a function of owning a private vehicle than that of modal choice: residents in Detroit simply do not have enough of choice in selecting travel mode. His suggestion is to increase access to car ownership for poor inner city residents, stressing the fact that the benefits from automobile ownership would far outweigh the burdens of pollution, congestion, costs of ownership and driving, and the time and costs involved in strengthening the existing public transit system. What is missing in this study is the nature of actual vehicle owners (their socio economic characteristics), their actual travel behavior, and resulting emissions estimations.

Vehicle emissions and travel behavior

There is an added dimension of travel behavior research that has focused on environmental burdens, such as gasoline consumption and/or pollutant emissions. Automobile dependent cities in the US consume excessive amounts of energy, much more so than cities in other countries (Schiller et al, 2010). Schiller and colleagues reveal that "an average American city of 400,000 inhabitants uses as much energy for private passenger transportation as an average Chinese city of 10 million people" (Pg. 8). Although residents make their travel choices taking congestion, time required and routes into consideration, rarely do they consider the environmental and/or energy requirements into this decision-making process.

Vehicle emissions are often researched as Greenhouse Gas (GHG) emissions in the transportation industry. The transportation industry is the fastest growing source of GHGs (Fitzgerald, 2010: Pg 145). Meyer (2010) states that transportation emissions account for over 28% of the overall emissions in the country. In the most basic and generic sense, emissions from vehicles are a factor of speed, acceleration, road grade, vehicle weight, rolling resistance and aerodynamic drag (Boriboonsomsin and Barth 2009). While some of these emission factors fall under the 'driving condition' aspects, some of them also fall under the 'vehicle technology' aspects. Both dimensions of emissions are discussed in more detail below.

Driving Conditions

McCollum & Yang (2009) investigate the ways in which we can reduce total GHG emissions in the long term, into 2050. They are of the opinion that the transportation sector has the most potential for emission reductions and that further emphasis should be placed on utilizing the many options that are available to reduce this sector's emissions. A study done by Ahn and Rakha (2008) used three emission models: 2 microscopic and 1 macroscopic. The microscopic models are supposed to be better as they use more detailed and have realistic data, as far as driving conditions are concerned. The microscopic models show that travel on arterial roads resulted in lower emissions and energy requirements compared to travel on highways, even if highway travel resulted in time savings. On average, energy cost savings of 18%-23% resulted with a travel time increase of about 4.3 minutes.

Lankao (2009) studied the impact that cities and urban transportation have on the atmosphere. They found that population size, density, and GDP per capita were the main influences on emissions. Cities, due to their density and land use characteristics, have 70% fewer emissions than suburbs (Fitzgerald 2010). Similarly, Stone (2007) looks at the land use patterns, specifically sprawl, and air quality in major cities in the U.S. He shows that land use has a direct relationship with air quality (measured through the ozone layer) as well as an indirect relationship through transportation, industry and power generation facilities.

Lindsey et al (2011) add the further dimension of topography to their analysis. They find that emissions are not strictly a linear function of VMT. Usually with uphill and downhill sections, the relative fuel consumption increases and decreases balance out. In their study on the effect of road grades on fuel consumption and emissions for light duty vehicles, they find that relatively flat routes increase the overall fuel efficiency by 15% to 20% over the uphill and downhill routes. Therefore, a longer route that is more "flat" may be preferable over hilly routes for the purposes of fuel consumption and emissions (provided the length increase is not more than 15% over that of the hilly route).

Vehicle Technology

There is also a new technology adaption dimension to the study of VMT, gasoline consumption and pollutant emissions. Plotkin (1999) discusses various technological advancements that can effectively lower GHG emissions from light duty vehicles. He is of the opinion that there are ways to improve emissions, but due to the low cost of fuel, these are likely not to have a great impact. Sperling and Gordon (2008) note that "if vehicle performance and size had been frozen in the early 1980s, current vehicles in the U.S. would consume 25% to 30% less fuel" (pg. 67). They talk about the changes in car technology and how we came to the point at where we are now. They assert that even though vehicle technology has improved over the years, this improvement has been offset by changing vehicle characteristics. Vehicles between 1980 and 2005 have increased in size, power, and energy-consuming features, as evident in the extensive adoption of four-wheel drive cars and trucks. The increase in size is evident in the increase in ownership of SUVs, minivans and pickup trucks. The increase in power is evident in the increase of 6 and 8 cylinder and turbo engines. And energy consuming features, such as four wheel drives, require more power and are heavier, and that means lower fuel economy (Sperling and Gordon, 2008).

In their study of the Chicago metropolitan area, Sperling and Gordon also find that the type of vehicle used in travel is important in determining emissions. Even though a majority of the vehicle fleet in the metro area was of the moderate emissions type, the minority of low-efficiency vehicles in the suburban areas—where most of the long distance travel was generated and undertaken—increased the overall emissions. Lutsey & Sperling (2009) have come up with a "supply curve" that shows the effects of various technological and fuel efficiencies on transportation emissions. They find that in order to achieve the climate reduction goal of 80% reduction in climate emissions by 2050, a substantial reduction in travel demand, advanced fuel technologies (decarbonized fuels) and vehicle technologies (minimal GHG emissions) will be needed by all sectors associated with the industry.

Costs associated with travel and emissions

Another line of research has focused on the costs associated with driving and related emissions. Morrow et al (2010) study the effects of various policy scenarios in reducing emissions. They are of the opinion that increasing the cost of driving is essential to the change in travel patterns, vehicle purchases, residential location and the main way to reduce transportation emissions. Similarly Carroll-Larson and Caplan (2009) estimate that a tax on the annual VMT would encourage people to reduce their travel. A tax of \$0.006 and \$0.02 per mile for passenger cars and light-duty trucks respectively, would reduce emissions of Particulate Matter (PM2.5) by 12% and 23%. Thinking of costs, Mashayekh et al (2011) did a study on the total costs of driving and emissions in 86 US Metropolitan Areas. The total costs included external costs of air pollution from personal vehicles in normal and congested driving conditions in these urban areas and this estimate amounted to \$53 billion annually. Factors such as ownership, maintenance, fuel, insurance and depreciation were included in total costs of vehicle use. External costs would be represented by factors such as health impacts and damages to the environment.

Similarly, the National Research Council estimated in 2007 that the health costs of emissions averaged to about 1.3 to 1.4 cents per VMT for gasoline vehicles. The pollution costs form a small fraction of 2.5% of total driving costs, yet when aggregated, they amount to a substantial figure. When adding in congestion, the costs are even higher. The 2009 Urban Mobility Report by the Texas Transportation Institute (TTI) estimated that costs of congestion in the U.S. in 2007 amounted to about $87.2 billion, which resulted in a time delay of 4.2 billion hours and extra fuel usage of 2.8 billion gallons. Mashayekh et al's (2011) results indicate that there was a total external emissions cost of $145 million per day, averaging to about $1.7 million per day per urban area in the US, further resulting in a cost of 64 cents per person per day or 3 cents per VMT. Part of this total external emissions cost is the cost associated with congestion, and this amounts to $24 million per day.

These costs signify that there is both an economic and social dimension to policies that aim to reduce VMT and emissions. Fitzgerald (2010) stresses the importance of public transportation as a factor in reducing emissions, while also being an important element of economic progress and local urban sustainability. In comparison to private vehicles, public transportation produces only 5% of the total carbon monoxide, 10% of the total volatile organic compounds, and 50% of the carbon dioxide and nitrogen oxide per passenger mile. Not only is it a more sustainable option for travel, it also has economic benefits. Fitzgerald (2010) states that the $47 million budget on public transportation in the U.S. helps support 1.7 million jobs in that industry on an annual basis. There are savings associated with this mode of travel as well. Public transit ridership saves 1.4 billion gallons of gasoline a year, an amount that translates into $6,200 annual savings for a two-worker household.

On a slightly different dimension, Moore, Staley and Poole (2010) emphasize that policies aimed at reducing VMT will have economic and social burdens of reduced mobility, access to jobs, and housing choice. They are of the opinion that climate change policies, in fact, should aim straight at reducing GHGs, instead of attempting to alter behavioral aspects of residents. York (2003) did a study that looked at the demographic, economic and socio political impacts on national car fleet data. He said that we need to look at different perspectives in order to get a full understanding of the transportation issue. Emissions from the transportation sector are influenced by three factors: 1) fuel consumption, 2) carbon content of emissions, and 3) vehicle miles traveled. No one method is strong enough to reduce emissions to meet targets set by various states throughout the U.S. A combined effort is the only way that current goals can be achieved.

Scale and gap in research

Research has often been done at various scales, from Schmalensee (1998), who does an international level comparison of emissions, to Drummond (2010), who looks at the state-level policy effects on GHG emissions. Wheeler (2008) assesses climate action plans implemented or initiated by each state in the U.S., while Yang and McCollum (2008) use California as a case study to analyze different scenarios where emissions may be reduced in the transportation sector. Environmental burden studies, analyzing fuel consumption for instance, have usually focused on scales beyond the neighborhood, mostly due to the availability of data (Dahl and Sterner, 1991a; 1991b). As an example, Su (2011) studies, at the urban/city scale, the effect of population density, congestion and road network densities on average household gasoline consumption for households in urban areas across the country. The author finds that households in cities with low population densities, higher freeway densities, or areas with higher levels of congestion, consume more gasoline.

Karathodorou et al (2010) analyze data from the 1999 Millennium Cities Database for Sustainable Transport, which is a compilation of information at the city scale for about 100 cities around the world, to study the effects of density on fuel consumption. They find that density does negatively affect fuel consumption indirectly through the number of cars owned and the distance traveled, but the analysis is at the city scale, which means that neighborhood level characteristics of spatial structure within the cities are simply averaged out.

The studies done at various scales are representative of the different components that make up emissions. Carbon Monoxide (CO) is usually researched at the micro level due to its immediate impacts on health, while Hydro Carbons (HC) and Nitrogen Oxides (NO_x) are studied at regional levels as they contribute to ozone formation (Bachman et al 2000). Carbon dioxide (CO_2) emissions have been increasing faster than any other type of emission, approximately 29% from 1990 to 2007 (Mashayekh et al 2011).

The neighborhood level of analysis, where the most varied and detailed information is found, is underrepresented in emissions and travel behavior research. Emissions, by their specific characteristics, are a dynamic phenomenon. Total emissions measured in any area are a combination of household, industrial, commercial, and vehicular sources. Vehicular emissions, as a source, are inherently dynamic, i.e. although vehicles can emit emissions when stationary, most of the emissions are created when the vehicles are in motion. So not only is the source dynamic, the pollutants, once emitted, are also subject to movement due to wind and natural atmospheric systems. Rarely do emissions that are created in one neighborhood stay within those neighborhood boundaries.

A disadvantage that many researchers have pointed out in this field of study is that they are restricted to data that usually cannot be obtained at smaller scales, specifically neighborhood levels). Data at lower levels of scale, such as the National Household Travel Survey are useful, however the sampling levels are quite low and that poses an issue. Brownstone and Golob (2009) use the 2001 National Housing Travel Survey (NHTS) California subsample database to study the effects of density on VMT and fuel usage at the household scale. They find that the effect of density alone on VMT is too small to warrant policies as a tool to constrain VMT or greenhouse gas emissions from personal vehicular travel.

Holtzclaw (2002), in his study involving the 2001 NPTS, suggests that the abundance of variables that affect auto ownership and use at a regional scale and the "lack of adequate neighborhood-level data has frustrated definitive analysis of these impacts. ….[The] NPTS data is insufficient in the number of respondents to allow analysis by individual metropolitan areas with statistical accuracy…. The nature of the NPTS data handicaps its use for the analysis of density, transit and other neighborhood impacts on vehicle availability and VMT" (Pg 5). Similarly, Lin and Long (2008) used the 2000 CTTP and NHTS data for their study and admit that "…as better data (e.g. finer spatial scale, more attributes) become available, finer representations of neighborhoods will result." (Pg 749). They conclude their analysis with the point that "..some of the issues are unlikely to be addressed adequately in regional transportation planning. Additional effort must warrant…local and neighborhood level [research]" (Pg 757). In short, researchers recognize the absence of neighborhood scales of analysis—which enables greater control of built environment characteristics—in gas consumption, emissions and VMT, and acknowledge the fact that a study at this finer scale would be beneficial to overcome the shortcomings of traditional, higher-scale data.

The general trend in research on this topic has been to compare and contrast neighborhoods with different built environments to see the differences in travel behavior and fuel consumption, while taking the differences in socio-economic characteristics of the residents living in these different areas into account. The gap in the research is two-fold: First, there is a paucity of research that explores how residents in similar built environments behave differently due to socio-demographic factors, save a few studies (LeDoux and Vojnovic, 2013; Scott et al, 2009; Williams, 2005). Vojnovic et al (2013) look at neighborhood disinvestment and travel behavior among residents within neighborhoods based on their socio-demographic characteristics. They study six neighborhoods in the Lansing, Michigan region and find that socio-economic conditions affected by neighborhood disinvestment in the declining urban core are critical to shaping travel behavior.

Similarly, LeDoux and Vojnovic (2013) study access to food stores by residents in two compact, pedestrian oriented neighborhoods in Detroit, Michigan, which are experiencing severe disinvestment and decline. They effectively show that residents of lower income neighborhoods shop for food supplies in ways that are contrary to popular thought. Rather than shopping at the closest store, they consistently shop at farther stores, thus exercising a choice that is shaped largely by social preferences rather than convenience factors. The study also shows that there is considerable variability in travel within the neighborhood that is based on socio-economic differences.

Second, there is a notable absence of research not only on the neighborhood scale analysis of environmental burdens (such as gasoline consumption and pollutant emissions), but also a general absence of studies that concentrate on the environmental burdens of residents in varying, but controlled, built environments based on different socio-economic characteristics. This forms the main aim of this analysis and this dissertation. The studies mentioned earlier, Brownstone and Golob (2009), Karathodorou et al (2010), Mindali et al (2004), and Su (2011), have all tried to reflect on the relationships between the built environment and fuel consumption at larger geographical scales. There has been no study that takes this notion further: exploring the socio-economic characteristics of the residents in varied built environments at the neighborhood level, in order to see more specifically the characteristics that impact fuel consumption and associated pollutant emissions.

Gap in Research, focusing on Detroit, MI

Another layer of research shortcomings is evident with the intended study area, the Detroit metropolitan region. Much has been written about the growth and decline of the City. However, detailed studies, at the neighborhood level, are few and far in between. Vojnovic et al (forthcoming) look at the travel patterns of residents in six different neighborhoods in the Detroit region. Similar to the above studies, the research finds the residents in similar built environments have different travel patterns that vary with their socio-economic characteristics.

The Detroit Area Studies are a series of studies based on an annual survey (done through a combination of interviews and mail-out surveys) carried out by the Sociology Department and the Institute for Social Research at the University of Michigan. The survey was conducted annually from 1951 to 2004 and focused on different themes and issues of public and personal life (ICPSR, n.d.). Although these studies are at the neighborhood level, and the data is rich and detailed, none of the studies have focused on transportation patterns and/or emissions. Research studies on emissions in Detroit are in line with broader emissions research discussed earlier. They look at emissions as affecting air quality and health of residents. For example, Duvall et al (2012) did a study on the sources of the fine particulate matter ($PM_{2.5}$) in various residential outdoor locations in Detroit, MI. Since PM concentrations have been known to be a causal factor in increased mortality, the US EPA establishes standards for air quality that aim to protect the public from the negative effects of PM concentrations. Detroit, MI is designated as an area that is in "non attainment" of these standards. This group of researchers found that residential areas differed in the measurements of the main sources of PM (particulate matter). Residential areas in downtown Detroit had road dust as the primary contributor, while areas near a highway had motor vehicles as the primary source. In summary, this study looked at the spatial variability in the source of one of the emission factors of vehicles. These studies, however, do not distinguish between contributions of these emissions or the socio-economic attributes of polluters.

Lindhjem et al (2012) conducted a study on the emissions and air quality estimations in the Detroit and Atlanta metropolitan regions. They created a new model (CONCEPT MV) that uses data from EPA's current emissions estimation model, MOVES2010, and estimates emissions on a road link by link basis, allowing for a more detailed estimation of vehicular emissions (light duty vehicles and heavy duty vehicles). What they find is that the new model, by using more fine grained data and inputs (at the road link level), estimates emissions that are much more accurate. They call for the importance of detailed data that would lead to truer estimations of emissions. Although this study is important for detailed emissions inventory, just like most other emissions studies, it does not touch upon the social characteristics and built environment as contributors to environmental burdens, that is gasoline consumption and pollutant emissions.

In general, emissions studies in Detroit, MI and most other places have concentrated on the sources and spatial and temporal variability in different emission factors. This leaves a considerable gap in current research. Just as it is important to know what the specific sources of emissions and air pollutants are, so it is important to know what the physical and socio economic characteristics are that pertain to the contributors of these sources. Research in Detroit is missing the combination of the social characteristics of the residents of different neighborhoods in the region (including the City) and their relationship with travel behavior and subsequent vehicle emissions, thereby establishing detailed "environmental burden" by specific neighborhood physical traits and socio-economic characteristics. Reiterating the conceptual framework, differences in the built environment do have an impact on travel patterns and behaviors of its residents. However, social and economic characteristics of the residents also have an important role in shaping travel patterns, vehicle characteristics, gasoline consumption, and pollutant emissions. This work will determine whether travel patterns and behavior, although influenced by the built environment, are determined more by the preferences and actions of residents, and these are derived from their specific socio-economic characteristics.

This study is important in two ways. First, it is conducted at a very disaggregated level—a neighborhood scale of research—indeed one of the lowest levels of analyses ever undertaken in exploring environmental burdens. Second, this analysis focuses on socioeconomic conditions in affecting travel and environmental burdens. The linkage of actual vehicle characteristics to specific household characteristics in travel behavior (and environmental burdens) is a critical addition to the exiting literature. An important added dimension to this research is that it not only focuses on residents that live in robust communities, but also includes two neighborhoods experiencing extreme disinvestment and decline in the City of Detroit. This is a unique dimension to travel behavior research and a significant contribution to the existing literature.

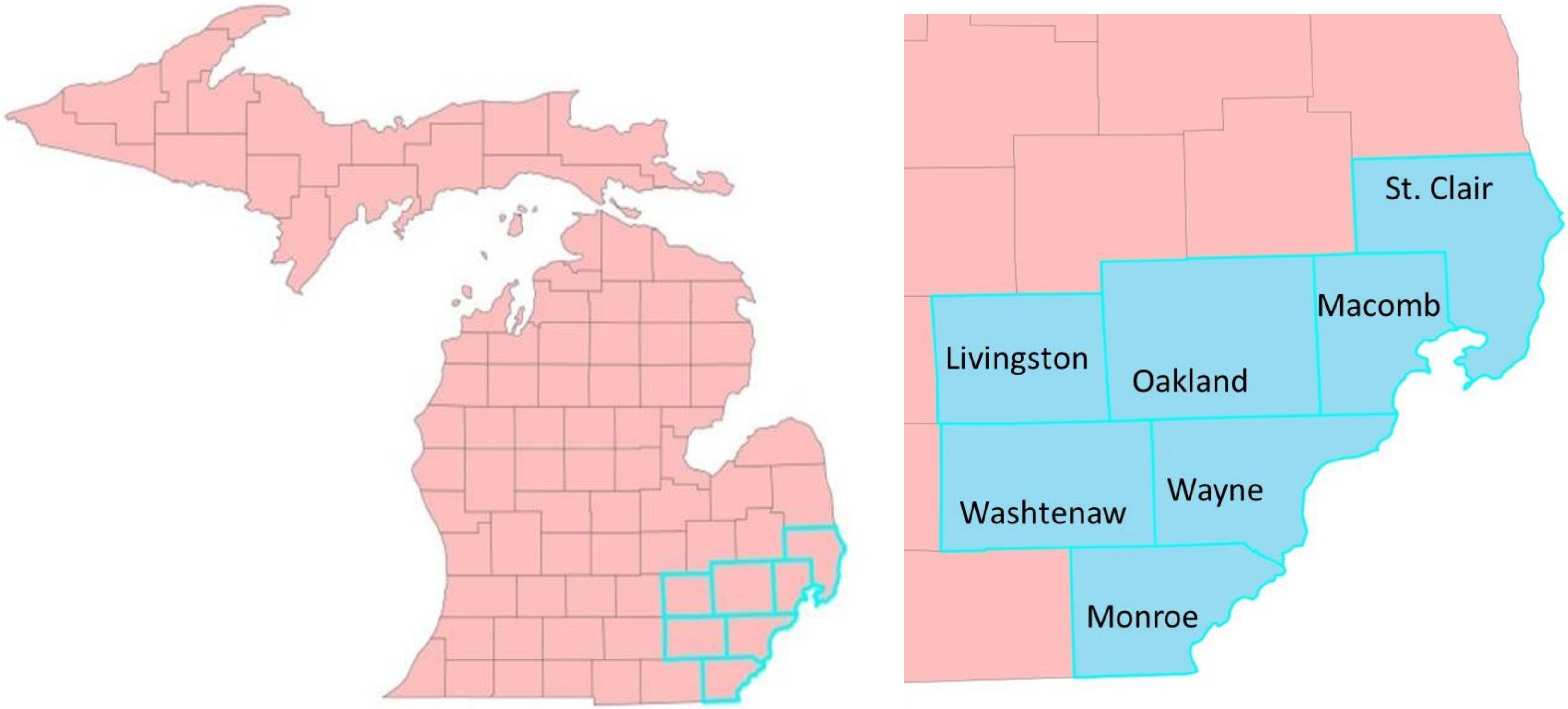
Chapter III - The Detroit Region

Introduction

The study area for this dissertation is the Detroit Region in southeast Michigan. This Region, akin to the jurisdiction of the Southeast Michigan Council of Governments (SEMCOG), includes the counties of St. Clair, Livingston, Oakland, Macomb, Washtenaw, Wayne, and Monroe. Detroit City is the largest urbanized area in this Region and as such, has had a tremendous influence on the morphology of the regional spatial structure. The purpose of this chapter is to give the reader an overview and highlight certain aspects of the history of Detroit. The review will provide a background for Detroit's growth and expansion in the years leading up to its current distressed state. This, in turn, will lead to a clearer understanding of why this region, and certain neighborhoods within it, were chosen as the focus for this dissertation. The City has been written about extensively. Various aspects of Detroit's past, and in greater detail, can be gained by reading the many excellent works on this subject (Darden et al, 1987; Darden & Thomas, 2013; Farley, Danzinger & Holzer, 2000; Gallagher, 2010; Galster, 2012; Sugrue, 1996; Thomas, 1997; Williams, 2009). This chapter however, gives an overview of Detroit's morphology through its growth, transition and decline periods, and provides a link to various economic, political and social forces that have shaped the city's built environment. In addition to providing a review of Detroit's history this chapter will also provide a discussion of the wider region and various aspects that lead to the selection of the six neighborhoods included in this research.

The Detroit region is unique in the sense that the city of Detroit itself is in one of the poorest counties (Wayne County, MI) in the country, even though its surrounding counties (for example, Oakland County, MI) are amongst the wealthiest in the nation. Tables 1 and 2 show the historic trends in per capita income and median family income by county for the Southeast Michigan Council of Governments (SEMCOG) Region.

Figure 1: The Detroit Region



*For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation

Table 1 – Per Capita Income by SEMCOG County

	1970	1980	1990	2000	2010
State of Michigan	$3,373	$7,688	$14,154	$22,168	$25,482
City of Detroit	$3,227	$6,215	$9,443	$14,717	$15,261
Wayne	$3,505	$7,608	$13,016	$20,058	$22,351
Oakland	$4,515	$10,658	$21,125	$32,534	$36,314
Macomb	$3,605	$8,655	$16,187	$24,446	$26,661
Livingston	$3,320	$8,323	$17,327	$28,069	$31,751
Monroe	$3,213	$7,356	$13,893	$22,458	$25,774
St. Clair	$3,048	$7,080	$13,257	$21,582	$23,960
Washtenaw	$3,767	$8,703	$17,115	$27,173	$32,529

Source: U.S. Census Bureau

Table 2 – Median Family Income by SEMCOG County

	1950	1960	1970	1980	1990	2000	2010
State of Michigan	$3,519	$6,256	$11,032	$22,107	$36,652	$53,457	$60,895
City of Detroit	$3,955	$7,715	$10,045	$17,033	$22,566	$33,853	$33,445
Wayne	$3,989	$6,597	$11,351	$22,134	$34,099	$48,805	$53,004
Oakland	$4,031	$7,576	$13,826	$28,803	$50,980	$75,540	$84,580
Macomb	$3,733	$7,091	$13,110	$26,666	$44,586	$62,816	$67,454
Livingston	$3,156	$5,775	$11,551	$26,339	$49,910	$75,284	$82,888
Monroe	$3,450	$5,892	$11,398	$23,281	$40,532	$59,659	$66,284
St. Clair	$3,245	$5,546	$10,125	$21,119	$35,678	$54,450	$59,952
Washtenaw	$3,435	$6,890	$12,294	$25,465	$47,308	$70,393	$84,770

Source: U.S. Census Bureau

The stark inequalities in the physical and social fabric of the region, visible at the county scale, show even more nuance and detail when viewed from a lower scale of analysis, such as a municipality or neighborhood. There is a visible, disproportionate percentage of the population segregated within the inner city, which is predominantly black and of lower socio-economic status than residents in the surrounding counties/suburbs (Darden and Kamel, 2000; Farley et al, 2000). Figures 2, 3, 4, and 5 depict these concentrations and population trends by race for the counties in the SEMCOG region. Detroit city itself has pockets of hope, evident in beautiful houses in a few neighborhoods, the riverfront area, and in the downtown employment cluster and entertainment venues, such as the sports stadiums, casino, and ethnic enclaves. Mostly, however, the city is saddled with abandoned houses, boarded up manufacturing plants, empty industrial lots and general physical deterioration.

Figure 2 – Population Trends by SEMCOG County

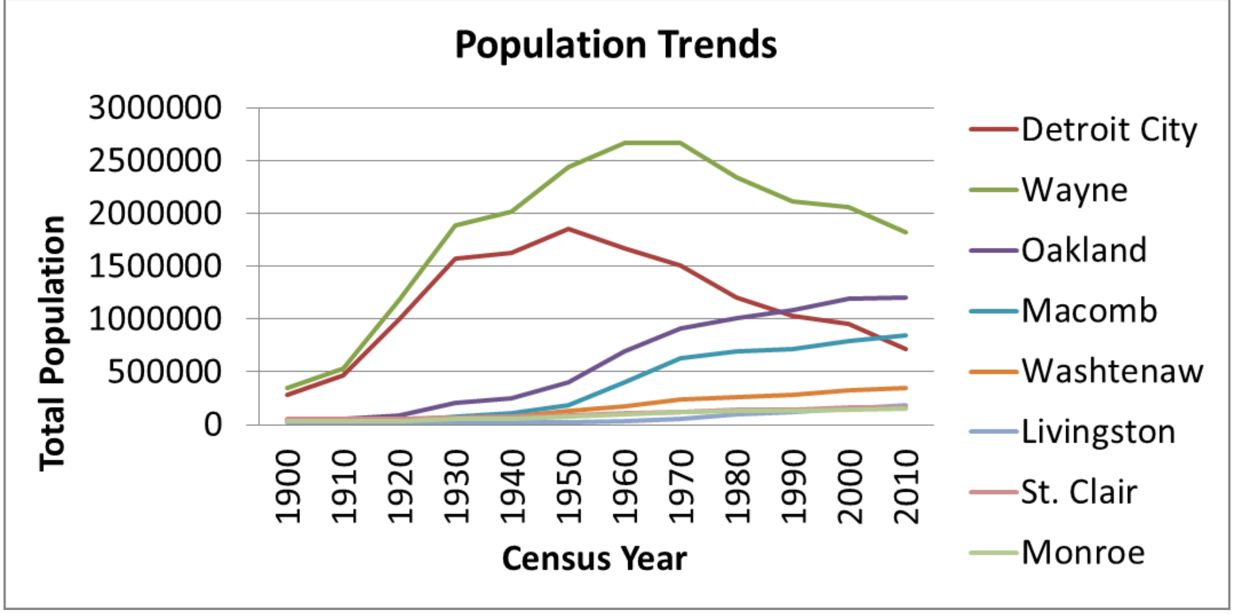


Figure 3: Percent White Population Trend by SEMCOG County

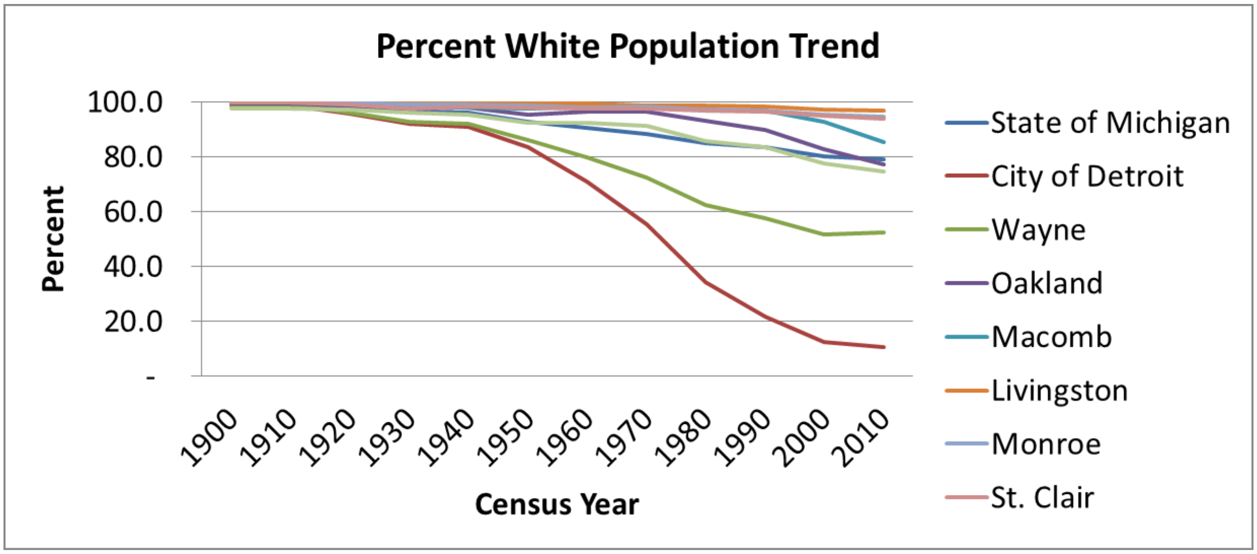


Figure 4: Percent Black Population Trend by SEMCOG County

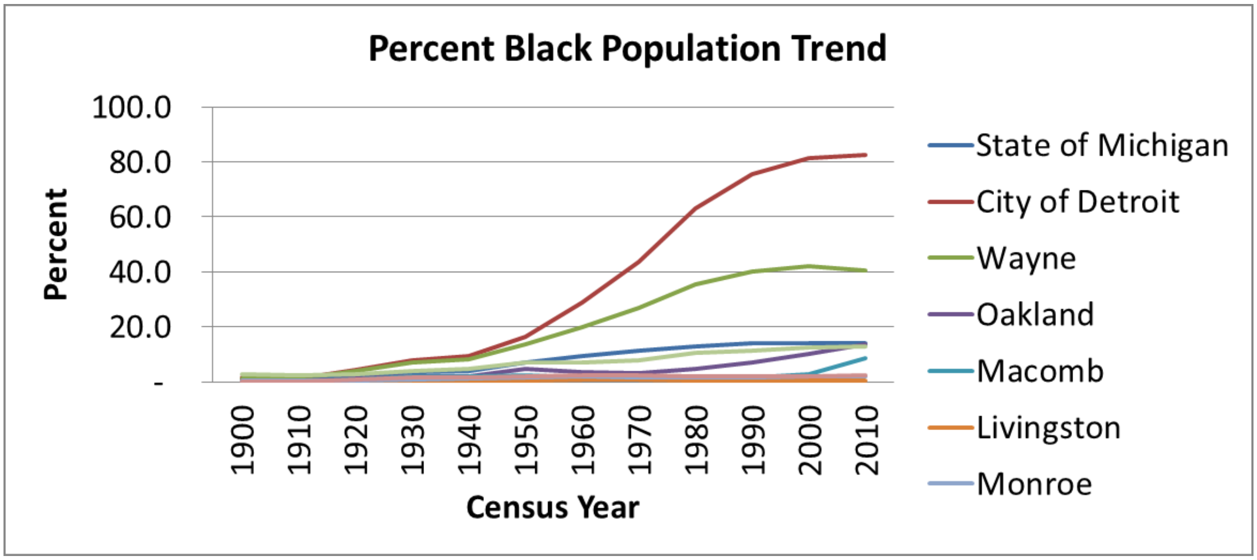
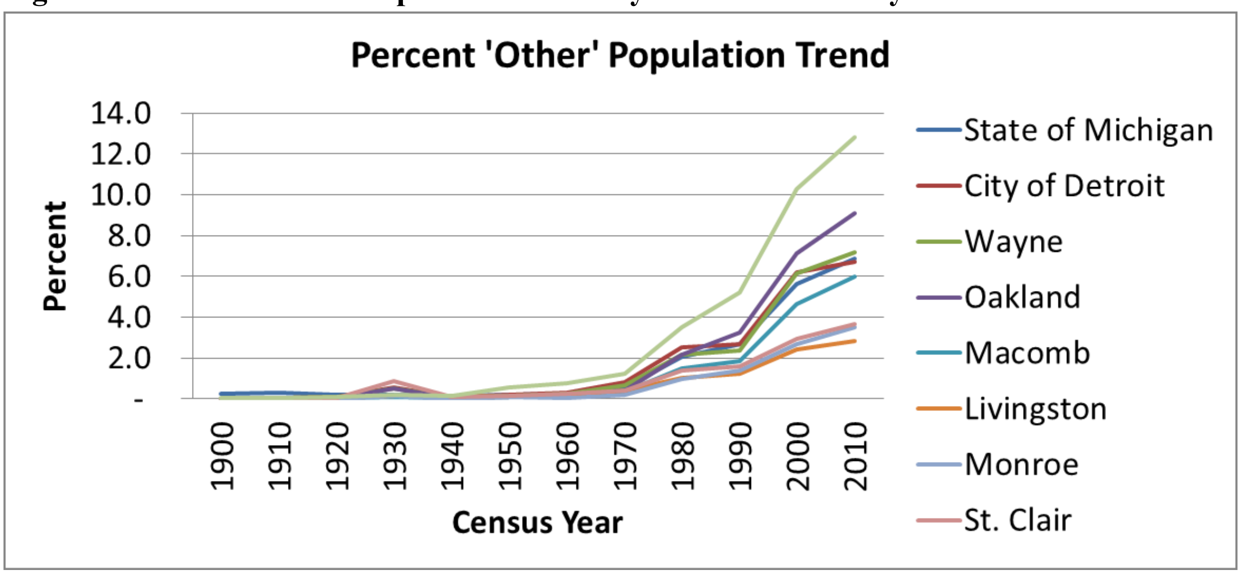


Figure 5: Percent 'Other' Population Trend by SEMCOG County



The Growth Period

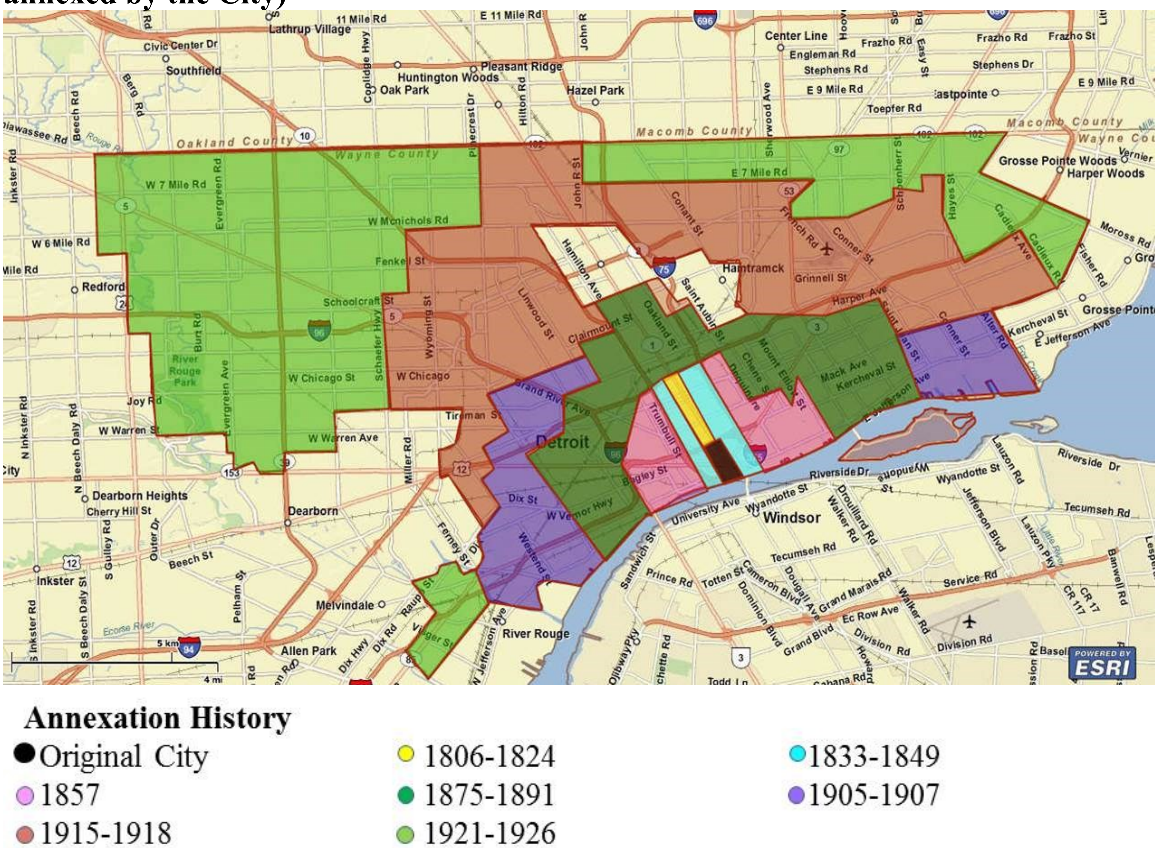
Economic/Industrial factors

At the beginning of the twentieth century, Detroit was a magnet for people and new development because of its rich manufacturing base. Manufacturing had long been the dominant industry of the region, with rail cars and stoves being important early industries (Voyles and Rodrique, 2012). The automobile industry expanded after World War I under the leadership of pioneers that had the economic strength to take advantage of Michigan's manufacturing base and its location and resources (Voyles and Rodrique, 2012). With automobile manufacturing expanding at unprecedented rates, the 'car' began to dominate the city, and particularly after the process of manufacturing became standardized. Henry Ford pioneered the assembly line process at his Highland Park plant (Galster, 2012). The city itself, nicknamed the 'Motor City', emerged as the center for automobile production and the Detroit metropolitan area grew because of the allied industries that fueled automobile manufacturing.

Municipal Expansion

As the population in and around the City of Detroit grew, annexation was used to increase the boundaries of the City so as to accommodate the growth and keep the taxes and businesses within the jurisdiction of the City. The figures below show Detroit's growth through the years. From 1815 to 1891, the City grew from 0.330 square miles in size to 28.350 square miles. The largest amount of land during that period, just under 7 square miles, was annexed in 1857. In the first quarter of the 20th Century, from 1906 to 1926, Detroit grew exponentially due to annexations (Galster, 2012). It expanded from 28.350 square miles in 1906 to its current size of 139 square miles by 1926, with the largest amount of land being annexed in 1925 (over 42 square miles) (Board of County Auditors, 1926).

Figure 6: Detroit Annexation Map (showing the years in which different land parcels were annexed by the City)



Social factors and related mobility

By the 1920s, the principle mode of travel had changed from horse-driven carriages to the automobile. Labor demands at the time were primarily for blue collar jobs that required repetitive, physical work to be performed (like working on an assembly line). Immigrants and migrants were flooding the city to be a part of Detroit's industrial success. The Ford Motor Company was the largest employer at the time and Henry Ford wanted to give his employees (mostly immigrants) a chance at a higher standard of living so that they could be assimilated into the American mainstream (Bates, 2012). He started the $5 wage per day, which is attributed to the movement that created the middle class (Counts, 2011). This wage level also meant that the employees could afford to buy a vehicle for themselves. More households owned cars and its ownership was more utilitarian than luxury based, fueling consumerism throughout the region.

Into the mid-20th century, the influx of people was a response to the growing demand for workers at manufacturing plants that catered to the automobile industry and eventually to the needs of the Second World War. The increases in population lead to an increase in the demand for housing. However, the housing supply was unable to keep up with the demand by the new waves of migrants entering the City. Established Black residential neighborhoods saw overcrowding and deteriorating conditions as more Blacks, attracted by the available jobs, tried to settle in the City (Bates, 2012). Some new segregated housing projects were constructed to accommodate the increasing Black population. For example, the Sojourner Truth Housing Project was built in the beginning of the 1940s to accommodate black residents (Farley, 2009). Black families did occupy the housing in Sojourner Truth, but only after violent protests by white residents in surrounding neighborhoods was controlled by military and police presence.

Into the 1950s, people, mostly whites, who could afford to move started leaving the City. They located in less crowded areas outside of the City and spurred the movement and growth of the Detroit suburbs. Preferences for larger homes on larger lots had a big impact on suburbanization and development in the surrounding region. The rapid growth and movement of the population into the suburbs, along with economic prosperity in the form of increased disposable incomes and lower energy costs, produced a development preference for single family, detached housing in open and less dense areas. These decentralization patterns also had clear racial imprints. The white population was suburbanizing and distancing itself from population sub-groups they considered a threat. The suburbs have been quite effective in keeping the Black population out of their jurisdictions through house pricing structures, gatekeeping institutions, and local development policies (Thomas, 1997). Steadily the segregation of the population became increasingly and clearly demarcated. Blue and white collar workers moved out from the central city to the surrounding periphery. Warren was one of these towns that was revamped from a rural area to a bustling blue collar town. The white collar residents moved more to the north and west of the City. Black inner-city neighborhoods developed very differently from the new white suburban neighborhoods. The City was slowly becoming an area for the black working class with lower incomes and fewer urban amenities.

Detroit had long been a major stop on the *Underground Railroad* system, a metaphor for the network that was used extensively to shift black populations from the southern states into the northern areas to free them from slavery. These populations would then either stay in the City and take advantage of the booming manufacturing industry and its employment opportunities, or continue north to Canada (Counts, 2011). Many of these migrants found work at the auto manufacturing plants such as the Ford Motor Company. Henry Ford had a big hand in increasing the morale and employment opportunities for black workers. Blacks had a larger range of jobs open to them at the Ford River Rouge plant than at any other plant (Ford or any other company). The black workers at the Rouge plant were in positions that were reserved for whites in other manufacturing companies (Meier & Rudwick, 1981). At the same time, management tried their best to avoid organized labor and unions amongst its workers. With Ford employees joining the United Auto Workers union in the 1940s, Ford moved operations to other jurisdictions to take advantage of new technologies and to get away from labor union powers (Sugrue, 2010).

A large part of the increase in population was due to the migration of black workers from the South. These workers came to the north in search of a good work environment, a decent wage, and to escape the persistent discrimination so entrenched in southern culture (Galster, 2012). The quick increase in the black population was being dealt with by segregating them into an area on the east side along Hastings Street, an area called 'black bottom' (which later got redeveloped into Lafayette park) (Williams, 2009). Interestingly, the name 'black bottom' was originally given by the French indicating the dark, rich and fertile topsoil of the area (Binelli, 2012).

North of Hastings Street was an area called Paradise Valley, which was the entertainment and business hub of the black residents. These bustling areas enjoyed strength and prosperity even in the Prohibition years, when the illegal sale of liquor was a dominant 'underground economic activity' (Bates, 2012). Money was flowing through the community, either through employment at Ford plants or through the circulation of money within the community through legal and illegal establishments. Segregation into certain areas was not the only form of discrimination practiced by landlords and housing authorities. The discrimination was also evident in the rents. Blacks shared their residential blocks with other eastern European immigrants, but they paid as much as about 50% more in rent for the same housing facilities, when compared to the new immigrants (Bates, 2012).

Transition Period

Economic/Industrial factors

The Great Depression years, during the early 1930s, witnessed decreased economic activity and incomes. In order to sustain the consumerism that was sweeping the country, new ideas and alternatives that replaced the iconic all-black utilitarian Model T with colorful and stylish vehicles were implemented by General Motors (Bates, 2012). Ford began suffering losses and market share of its products. Its workers were hit hard. Unemployment, reduced work days, and mounting home payments added to the woes of the working class, not only employed at Ford, but at Chrysler and General Motors as well.

The Role of Roads, Highways and the Automobile

Fueling the mobility associated with economic prosperity was the Federal Highway Administration's Interstate Highway Act of 1956, which substantially increased the movement of American people across urban regions and beyond (Weingroff, 1996). Part of this very ambitious project was the construction of the Lodge freeway and the later the Edsel Ford expressway that was purported to improve the travel of people from the outer areas of the City into the Central Business District (CBD). Travel by highways and expressways was encouraged by policies and automobile companies that tried their best to discourage the use of public transit (Whitt and Yago, 1985). The 'Big Three', Ford, General Motors and Chrysler had used all their powers to keep the automobile the primary vehicle for mobility and dissuade public transit permeation within the Detroit region. The Interstate Highway system was moving along so rapidly and with such intensity that support for public transit, and also its federal funding, faded away. This affected the service and customer satisfaction levels for whatever transit was available at the time. The city that brought the automobile industry to life was left with a dismal transit system (Vojnovic and Darden, 2013).

In the early 20th century, making the best of whatever they had, Detroit's African Americans took control of Black Bottom and Paradise Valley, making these areas highly successful. Businesses, theaters, services and facilities meant solely for the black residents were mushrooming through the area during the 1920s and into the Prohibition period (Bates, 2012). However, this success was not meant to last long. Both the black dominated areas of the City (Black Bottom and Paradise Valley) were targeted during the period of Urban Renewal in the late 1950s. Housing projects and freeways replaced Detroit's thriving Black neighborhoods. Housing projects took out the poor residents with the promise of giving them better housing once the redevelopment was completed (Thomas, 1997). Instead they were displaced altogether and had to find other areas of the city to call home.

Similarly, other government policies have also had a hand in the decline of the inner city area of the Region. Investment in and subsidization of suburban infrastructure has been a big factor in suburbanization (Vojnovic, 2009). During the post World War II period, the Federal Housing Authority (FHA) and the Veteran's Administration (VA) insured and subsidized mortgages to suburban residential areas created an attractive incentive for people to move to the suburbs and realize their 'American Dream'.

Initially, the mechanism for coping with growth was annexation. However, the state of Michigan used the 'home rule' power in the state constitution, which subsequently allowed places to get incorporated so as to create new municipalities, with the result that segregated fragmentation occurred without any control. Consequently, the city boundaries stopped expanding in 1926. Incorporation of municipalities has led to fragmented governments and policies (Thomas 1997). Between 1950 and 1980, fifty incorporated places were added to the Detroit metropolitan area (Darden, 2009). This fragmentation harbored a sense of control for suburbanites as they demarcated their area and consequently fostered pro-sprawl growth, imprinting and stereotyping the socio-economic inequalities (Galster, 2012).

Social factors and related mobility

Rising racial issues were not only felt through housing segregation, but permeated into the public school system as well. In 1954, the US Supreme Court case of Brown vs. Board of Education ruled that segregation within public schools was illegal and it was against the Fourteenth Amendment that gave equal rights to all citizens (Brown v. Board of Education, 1954). However, the 1974 landmark case of Bradley v. Milliken in the Supreme Court ruled that since the suburban municipalities were not segregating students but were open to all students of the municipality (that essentially had primarily white residents), they were not in fact promoting segregation (Bradley v. Milliken, 1974). This ensured that suburban, fragmented municipalities could effectively keep the inner city children out of their schools (just as they had kept the inner city residents from entering their suburban communities). The Detroit Public Schools were subsequently left with a segregated, concentrated pool of black and poor students. The strain on racial relations between the two groups has been stressed upon by researchers who posit that the blacks have been continuously discriminated by whites in all areas of everyday life choices, be it housing, employment, or education (Darden et al., 2007; Thomas, 1992; Sugrue, 1996).

During the 1950s and 1960s, huge tracts of land needed to be cleared for the newly sanctioned highways and the black neighborhoods were the ones that bore the brunt of these projects. Just like in urban renewal projects, the established black neighborhoods (residential and commercial) were condemned and razed so that highways could be built and people could travel into the city at high speeds. Mayor Jeffries had condemned 129 acres of Black Bottom so that the Chrysler freeway could be built (Binelli, 2012). The rest of Black Bottom was later replaced by Lafayette Park. In total, about 5,000 buildings were demolished, most of which belonged to the black community (Williams, 2009).

The widely known incentives for home-buyers in the growing suburban areas were attracting middle class residents out of troubled Detroit and into the newly built residential suburbs. However, these incentives were only available to the white population (Darden, 2009). The black population would be overtly rejected for suburban home mortgages. Appraisers would be allowed to mark primarily black neighborhoods with red ink, indicating high risk areas where government subsidies and mortgage financing should not be given, hence the term 'redlining' (Darden, 2009). The practice went on for three decades, from the mid-1930s to the mid-1960s (Renolds, Danziger and Holzer, 2000). If federal programs, such as these would be challenged and overruled, local governments had other ways to keep racial segregation going – namely zoning measures and housing restrictions (Galster, 2012). Not only the governments, but real estate agents played their role in fostering segregation as well. Keeping the interests of their white clients in mind, they would 'steer' black potential home buyers to areas that were predominantly occupied by the same race. After all, "…whites did not care to live with blacks and could not get FHA/VA-backed mortgages if they did; blacks…would not get FHA/VA-backed mortgages in any event" (Galster, 2012; pp. 148).

The situation was so severe that a developer, in order to build a white neighborhood near Eight Mile road (which had black neighborhoods in close proximity), had to erect a concrete wall, six feet high and half mile long along the black neighborhood so as to physically separate the black and white communities (Rhodes and Jeffries, 2010). This was done because the Federal Housing Administration would not have backed mortgages in the white neighborhood because it was so close to the 'redlined' black neighborhood. Mortgages were approved in the area after the wall was erected.

As if it was not enough that the government and the market were doing their best to keep residential neighborhoods segregated, the homeowners themselves used harassment and restrictive covenants to do their part in keeping the unwanted out of their neighborhoods (Galster, 2012). Restrictive covenants were like clauses added to property deeds that restricted future uses and certain kinds of occupants within a neighborhood. These covenants were used widely until 1948, when the Supreme Court ruled against them in the Shelley vs. Kraemer case saying that they were not enforceable by law as they were private agreements and as such they were against the Fourteenth Amendment to the Constitution that gave equal protection to all citizens (Shelley v. Kraemer).

The exodus from the City was primarily by white residents. Housing policies, gatekeeping institutions and real estate markets would effectively keep the black population within the city and segregated in certain areas, and would steer them away from or refuse to help them attain the quality of life and residential choice that their white counterparts were demanding and receiving. Apart from such formal and structural methods of racial segregation, social effects such as racial solidarity have also had an impact on residential preferences (Bledsoe et al, 1995). In a survey administered to black residents in inner city Detroit and suburban Detroit, in segregated neighborhoods as well as integrated neighborhoods, Bledsoe and colleagues (1995) find that there is greater solidarity among Blacks in segregated neighborhoods when compared to their counterparts living in integrated neighborhoods, forming one of the reasons why Blacks may choose to live in neighborhoods that are more segregated/homogenous. However, social and economic conditions of those living in the suburbs were found to be much higher than those living in the inner city, resulting in a dilemma between increasing racial integration or the advancement of the Black population based on the strong bonds of solidarity (Pg 453).

Any discussion of the Detroit region is practically incomplete if the racial tensions and riots are not brought up. Racial tensions had been simmering since the beginning of the 20th century. The early 1940s witnessed a race riot that started on Belle Isle and engulfed the entire City, starting on June 20th 1943 and lasting for 36 hours. The end came after six thousand federal troops were called in to help end the disturbance that took the lives of twenty-five black and nine white residents (Binelli, 2012). Although the 1950s saw growing population and suburbanization, it also witnessed increased racial hostility. Darden and Thomas (2013) describe the racial resentment taking life in the form of hostility by white residents towards black families that tried to move into a predominantly white neighborhood. The exacerbated results of failed urban renewal programs that uprooted and displaced entire black neighborhoods added to the frustration felt by this dislodged and mistreated community. Hostility and segregation efforts towards the black families had the effect of them living in "…overcrowded, poor ghettos, which became breeding grounds for angry black youth waiting for an opportunity to explode." (Darden and Thomas, 2013; Pg 5)

Two decades later, the riots of 1967 did worse damage. Following a raid on a ‘blind pig’ (an after-hours drinking establishment) by the police, what was expected to include a small number of arrests (about 20 people) turned out to be an issue that got out of control, resulting in violence, death and a section of the city being burnt down. The riots went on for five days, over forty-three people died, about seven thousand people were arrested, and about three thousand buildings were burnt (Binelli, 2012). Only after the influx of the police, the Michigan National Guard and the U.S. Army to contain the rioting did the rampage die down. Subsequently, President Johnson created an eleven member commission, the National Advisory Commission on Civil Disorders, popularly known as the Kerner Commission - to look into urban riots. They stated in their 1968 report that “..our nation is moving toward two societies, one black, one white – separate and unequal.” (Kerner Commission, 1968). They indicted the white society for isolating the African American community and urged the government to take action to aid the black community so that they can avoid further racism from the dominant race. However, the social effects of these outbursts resulted in people, and generally whites, continuing to be encouraged to move out of the city and into the surrounding suburban areas to avoid being in the midst of such violent conflicts.

Period of Decline

Economic/Industrial factors

White flight was not the only exodus out of the city during the second half of the 20th Century. Retail, commercial, and industrial investment also moved out of Detroit. In addition, the ‘big three’ automobile companies (Ford, Chrysler and General Motors) overpowered the other automobile manufacturers in the area and drove them out of business (Sugrue, 2010). In addition, the ‘the big three’ moved to expand their businesses, but did so in the outskirts of the City. Following them, smaller allied industries moved to the outskirts as well. With the Ford employees joining the United Auto Workers union in the 1940s, Ford moved operations to other jurisdictions to take advantage of new technologies and to get away from labor union powers (Sugrue, 2010). In the 1950s, about 150 new plants (manufacturing and allied industries) were built in the suburbs of Detroit, with one third of these relocating out from the City to make this move (Galster, 2012). Detroit witnessed “…a dramatic intraregional shift in the location of all economic activity – manufacturing and nonmanufacturing alike – in the last half century” (Galster, 2012; pp. 51).

In the last few decades of the 20th century, the economic downturn facing the automobile industry crippled the City that was built around it. Competition from international companies, and particularly from Germany and Japan, with new manufacturing procedures left the Big Three in dire straits and they suffered significant losses (Galster, 2012). To keep up with the competition, the auto companies employed more technology driven procedures that required fewer workers. The economic crisis exacerbated the white flight and the City was increasingly left with an unskilled, lower income, segregated population base and a suffering local government. With jobs moving out of the City, and unemployment rising within the City, property prices and taxes declined. This affected the local finances and public services suffered, and particularly the Detroit public school system (Mirel, 1999).

Built environment factors and related mobility

The second half of the century witnessed a decline in Detroit like no other city in the country had experienced. Commuting was not an issue to suburban residents and was preferred over living in the inner city. Although some studies have shown that the move to the suburbs by residents and commerce alike helped move commutes out of the city center and into the suburbs, thus alleviating congestion, other studies showed that suburbanization did not move commutes out of the inner city, but only increased commute times as people traveled longer distances into the inner city areas for work (Kirby and LeSage 2009; McGuckin and Srinivasan 2003).

The election of the City's first black Mayor, Coleman Young, in 1973 marked an optimistic hope for the residents. Young has done many things to improve the City, its economic slump, racial tensions and housing markets. One of these efforts was targeted at rebuilding residential neighborhoods that had abandoned and vacant lots (Farley, Couper, and Krysan, 2007). These efforts from Young's office and his successors (Archer in 1993 and Kilpatrick in 2003) focused on giving subsidies to developers to build in the City. Developers were initially reluctant to build in Detroit because no one wanted small-lot and small-sized housing, together with the fact that these would be expected to be bought by middle class black residents (as the white residents were reluctant to move back into Detroit). However, these subsidies did attract some developers to reinvest and rebuild certain parts of Detroit.

In the last decade of the 20th century and into the first decade of the 21st century, improvements in the housing market saw private redevelopment efforts in the downtown and surrounding areas, made possible largely through heavy subsidies provided by government. Ryan (2006) reported that all developments during the 1990s and early-2000s included some form of government subsidy. Subsidies ranged from creating Neighborhood Enterprise Zones (a tax abatement for 10 years on a new home purchase), to large and costly subsidies for site remediation and provision of foundation-ready lots (Ryan, 2012). For example, the Victoria Park redevelopment in the Jefferson-Chalmers area received subsidies to the tune of $125,000 per house (Ryan, 2012). Most of the other deteriorated parts of the City received little incentives for developers to build as the market was uninterested in purchasing property located in 'troublesome' areas. Renewal efforts targeted at many of the neighborhoods were abysmal. As effectively expressed by Ryan (2012), "the growth machine reproduced urban renewal's worst features – involuntary displacement of low-income homeowners for a mostly failed attempt to attract "high-end" homes – without bringing any of the stabilizing influences that large-scale government intervention in an abandoned neighborhood might have delivered" (Pg. 88).

The Detroit suburbs, on the other hand, continue to prosper with vibrant residential and commercial activity. Suburban home values are among the highest in the country, educational facilities (schools and universities) are among the top ranked and quality of life of the residents keeps drawing more people away from the City (Woosley, 2008). Infrastructure, public services, and entertainment are top notch. This has resulted in a blatant divide between the city and the suburbs. The population in the suburbs consists mostly of whites, along with an increasing presence of Asians, with the socio-economic composition of these residents consisting extensively of middle and upper income earners.

Both the city and the suburban residents are eager to hold on to their assets, be it financial or physical. The city refuses to delve into land banks, has declined to hand over the Cobo Center to a regional governing authority, or to enter into joint regional control over its water system, being reluctant to give up any more of its 'assets' to the white majority in the region (Galster, 2012). On the suburban front, Oakland County turned down a proposal in 2005 for increased taxes to rehabilitate cultural attractions in the City that would benefit both Wayne and Oakland counties. Similarly, suburban residents, until recently, refused to be a part of regional transportation agreements offered through the Suburban Mobility Authority for a Regional Transportation (SMART) bus system. They do not want increased taxes to foster a bus transit system that mostly poor blacks would make use of (Galster, 2012). However, a Regional Transit Authority was created in March 2013 and work plans for a bus rapid transit system for four counties in the SEMCOG region (Wayne, Oakland, Macomb, and Washtenaw) are currently being created. This cooperation was mandated by the federal government, as a precondition for receiving funds for a light rail line that has been proposed and declined 23 times in the past (MDOT, 2013).

Social factors and related mobility

While Glaeser, Kahn and Rappaport (2008) state that more than 19 percent of the central city population in general are poor, the 2010 US Census figures show that over 37 percent of the population in Detroit City are poor. Home values are at an all-time low and residents are locked into deteriorating neighborhoods (Green, 2013). Increased city taxes have not been able to improve the condition of public services, while they have added an extra burden on Detroit's poor.

Racial tensions as well as class conflicts have been vital in the decentralization of Detroit (Darden et al 1987). As the boundaries of urban Detroit grew, so did segregation, racial conflict and a distinct 'hollowness' within the central city. Residents continued to move to the suburbs, a condition that has only worsened, as the most recent census shows a decrease in population in the city that has brought population levels down to that of 1920 (Census, 2010). The Detroit metropolitan area has seen slightly declining inner city segregation and increased suburbanization of black residents, however, blacks in suburban Detroit are still highly segregated (Darden et al, 2007). It is a frustrating time for Detroit residents who have to deal with unemployment, discrimination, high taxes, crime, and property disrepair and devaluation. The extreme scale of disinvestment and decline in the city has received extensive national and international media coverage. In the words of Chris Hansen (2010), who recently described the condition of Detroit on *Dateline NBC* as follows:

> They litter the landscape, thousands and thousands of abandoned homes. And just like these buildings, Detroit is a shell of its former self. One third of the people here live in poverty. Almost half the adults are illiterate, and about 75 percent of kids drop out of school. I could be describing some ravaged foreign nation, but this is the middle of America.

The Outlook: Dismal, yet hopeful!

The 21st Century sees little improvement in the situation facing the City and its people. Darden et al (2007) show that the inequalities present between the black and white residents in the state of Michigan has only increased in the four decades since the 1967 riots. Residents are still leaving, with the 2010 Census showing the City of Detroit as having plummeted in population from about 950,000 in 2000 to 714,000 in 2010. The City that was once one of the largest in the country in terms of population (ranking in fourth place) is now smaller than Austin, Texas and Charlotte, North Carolina, ranking only in eighteenth place by size (Seelye, 2011). Two-thirds of the City's children under the age of five years live in poverty and the unemployment rate has topped 15% (Data driven Detroit, 2012). Moreover, the City has just filed for bankruptcy, the ex-mayor went on trial for embellishment of public money, and the big three auto makers had to be bailed out by the government in order to avoid collapse (Cho and Marr, 2009; Davey and Walsh, 2013; McClam, 2013;).

The public school system is inferior in the quality of education, with both the level of segregation and the dropout rates being among the highest in the nation. Greene and Winters (2006) show that the Detroit public school system has the highest dropout rate in the nation in 2003, at 58%. The dropout rate has been decreasing in recent years, although it still remains high in national comparisons (Detroit Public Schools, 2011). Crime rates continue to remain high. The number of fires in the City is still high, with about 30 structure fires being reported each day (Schwartz and Gold, 2012). The landscape is dotted with abandoned homes and businesses and almost one third of the City lies vacant.

The vacant landscape is considered the biggest challenge and also the biggest opportunity. The dilemma of how to utilize these vast amounts of vacant land that are starting to look like rural or natural landscapes is what many public officials are contemplating. Detroit has been symbolized through nicknames several times throughout history. Starting off with it being the ‘industrial boom town’ in the late 19th century to the early 20th century (Maynard, 2011), followed by it being the ‘arsenal of democracy’ throughout the second world war (Detroit Historical Society, 2013). It embraced planning in the second half of the 20th century and adopted the ‘model city’ icon, and after that things went downhill (Thomas, 1997). ‘Murder capital’ (Mach, 2013), ‘ghost town’ (Hitchens, 2011), ‘shrinking city’ (Independent Lens, 2013) – these have all been names describing the city as it has been journeying through its troubled times. Galster (2012) offers four “cold statistics” that summarize Detroit’s self-propelling decline: “From 1950 to 2005, Detroit lost 29 percent of its homes, 52 percent of its people, 55 percent of its jobs, and 60 percent of its property tax revenue” (pp. 238).

Even amidst all this, there is an undying hope and struggle to reinvent the City. The devastation has left Detroit in such a state that it could start off as a clean slate for new inventive and creative ideas. The City still has a relatively high density – averaging over 5,000 people per square mile as reported in the 2010 Census (down from about 13,000 people per square mile in the 1950s and 6,500 residents per square mile in the 2000 Census). Comparatively, cities such Phoenix with a density of 2,900 residents per square mile and Dallas with a density of 3,400 residents per square mile are much more sparse (Gallagher, 2010). The Heidelberg Project, a block of residential area turned into an art space, has gathered attention in the past and still does (The Heidelberg Project, 2013). The Project attracts fifty thousand visitors annually and has extended to a few blocks of the surrounding residential area.

In other areas of Detroit, volunteers work tirelessly to maintain City parks, demolish abandoned homes so as to curtail crime activity, induce community involvement, and help keep a vigil out on neighborhoods (Blight Busters, 2013). The food desert label that has been given to the City is also on the verge of being remedied. The owner of Hantz Farms has been purchasing land in the city to farm fresh fruits and vegetables for the residents of Detroit (Huffstutter, 2009). Whole Foods has been given a subsidy to open a mini-store in the Midtown portion of the City, thereby introducing a space for fresh and healthy produce to be sold to the residents (Gallagher, 2013). Meijers is also opening a store at Woodward and Eight Mile, which is poised to open in July 2013 (CBS Detroit, 2013).

In addition, Detroit is a major-league city, with the Red Wings, Tigers and Lions all having their arenas in the downtown. There are three casinos and many restaurants and bars attracting a bustling life in the city's core. Many of the city's residential neighborhoods still have beautiful homes, are well-kept and command a high price, and most of them are on the National Register of Historic Places. These include neighborhoods such as the Indian Village, Bush Park Historic District, Woodbridge Historic District, Palmer Woods, Rosedale Park and the East English Village (National Park Service). Jazz music venues, artist homes, and urban agriculture are all on the table for this struggling city. How the City charts its future, is yet to be seen.

Commentary

The Detroit region has gone through extreme conditions over the last century. It has cradled the automotive industry and raised it to levels that have prompted innovation and unprecedented strategic practices. However, just as with any product and its business cycle, the automotive industry experienced a wave of decline, which coupled with other racial issues of the time, affected the Detroit Region in many and devastating ways.

The Region has been a poster child for showing the effects of concentrated poverty and high levels of segregation. The exodus of the middle class white population to the suburbs has left the city with vast amounts of vacant land, abandoned properties, inferior public services and a poor and struggling workforce. The situation is changing, albeit at a slow pace. Reinvestment is being welcomed. However, race and class is still a major issue, with the majority black population, coupled with high rates of poverty, living in this city characterized by unprecedented disinvestment and decline.

With disinvestment and decline, mobility and access to basic amenities in the city has been also affected and in dramatic ways. . Mobility has been particularly shaped by the lack of an extensive public transit system for a city of this size and vintage, leading to over-dependence on the automobile (Vojnovic and Darden, 2013). Deteriorating conditions of streets and sidewalks, lack of vibrant shopping areas and uninviting public spaces are also built environment factors that have impacted mobility. Social factors have also played a role in determining transportation through this city. The perception of safety and preferences of the residents to go to certain destination over others has been important in shaping mobility. This is a city that has been traditionally built to induce transportation in all forms (motorized and non-motorized) and has had the text book qualities of high density, high connectivity, mixed land uses to promote high accessibility throughout the once active and vibrant urban core. However, disinvestment and decline in many of its neighborhoods—which have removed many necessary daily destinations from the city—coupled with a deteriorating built environment have adversely affected travel in this city. In addition, social influences and prejudices have taken on a more dominant role in how and where the residents travel.

The next chapter in the dissertation will discuss the study areas in greater detail. General descriptions of the cities and/or towns in which the six study neighborhoods are located, as well as objective built environment data on the neighborhoods themselves, will be provided. The rationale for the selection of the areas and neighborhoods for this research will also be explained.

Chapter IV - Study Neighborhoods

Introduction

This chapter delves into the details of the study area and the specific neighborhoods included in the research. Beginning with a description of the larger general region, the Detroit Region and the SEMCOG jurisdiction, the chapter progressively focuses in on the five cities/towns included in the study. The discussion then turns to the characteristics of the very neighborhoods within the selected cities/towns that are part of the analysis. Appendix A shows the comparison of some socio-economic and demographic variables between the City/Town that each study neighborhood is located in, the Census tracts that encompass the study neighborhood and finally the study neighborhood itself. In this way the characteristics of the residents in each neighborhood will be viewable in light of the larger geographic region that they live in. In all, six neighborhoods are included in this study, which are then grouped in twos to form three distinct neighborhood typologies on which the analyses are conducted. This chapter describes and details the six neighborhoods that are the basis of this research.

The Study Region

The City of Detroit is nestled within Wayne County. The urban area is delineated by the Tri-county Region of Wayne, Oakland and Macomb. A larger reference area, the Detroit-Warren-Livonia Metropolitan Statistical Area, adds the counties of Lapeer, Livingston and St. Clair to the Tri-County area. The Census Bureau designates the Detroit-Ann Arbor-Flint area as the Consolidated Statistical Area (Figure 8). The CMSA adds the counties of Genesee, Monroe and Washtenaw to the MSA. Lenawee was originally included in the CMSA, however, the

Census dropped it from the CMSA in the year 2000. The Southeast Michigan Council of Governments (SEMCOG) is a regional governmental entity that has jurisdiction over Monroe, Washtenaw, Wayne, Livingston, Oakland, Macomb and St. Clair counties. The SEMCOG region is slightly smaller than the CMSA region, and is a regional association of governments that aims to solve the issues and challenges of the Southeast area of Michigan.

Figure 7: The Detroit Tri-County Area

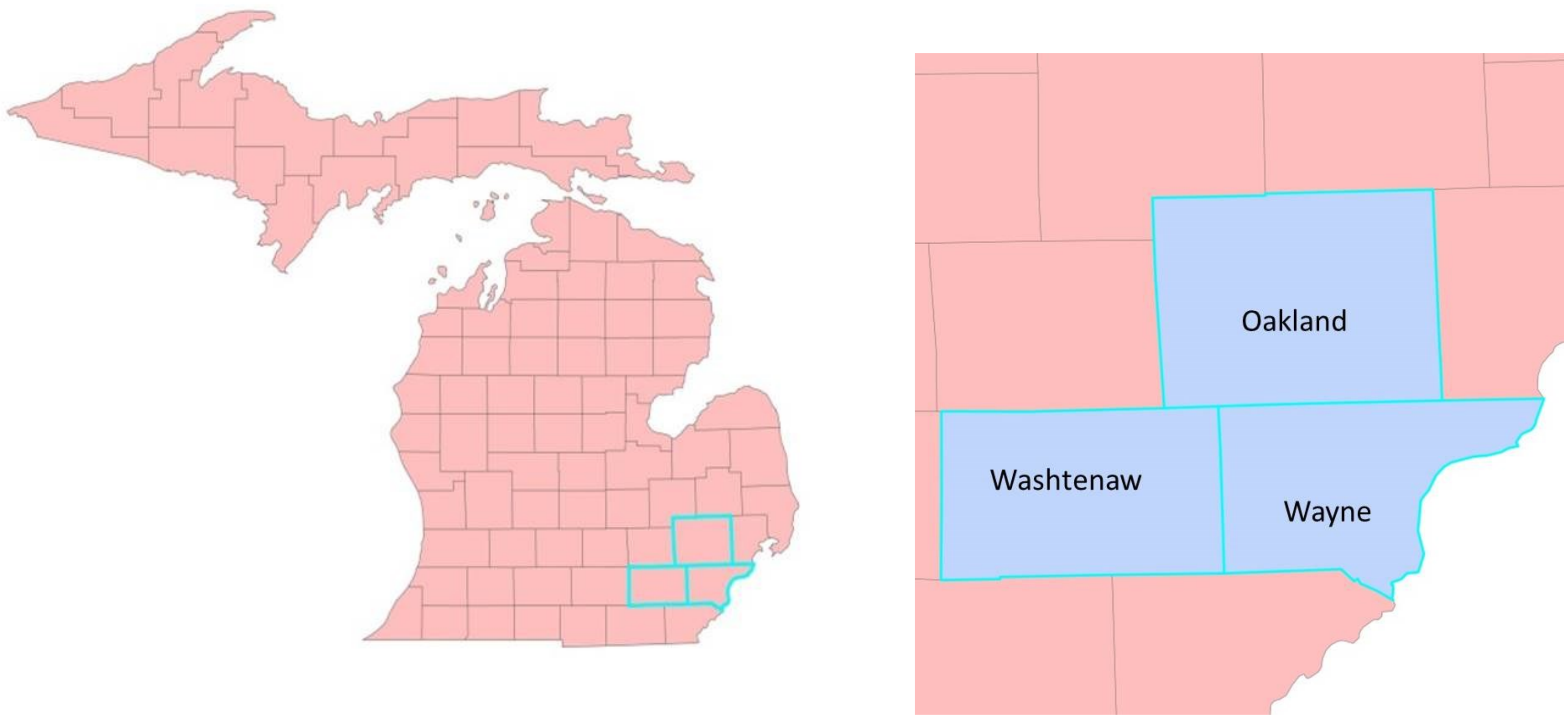


Figure 8: The Detroit-Ann Arbor-Flint CMSA

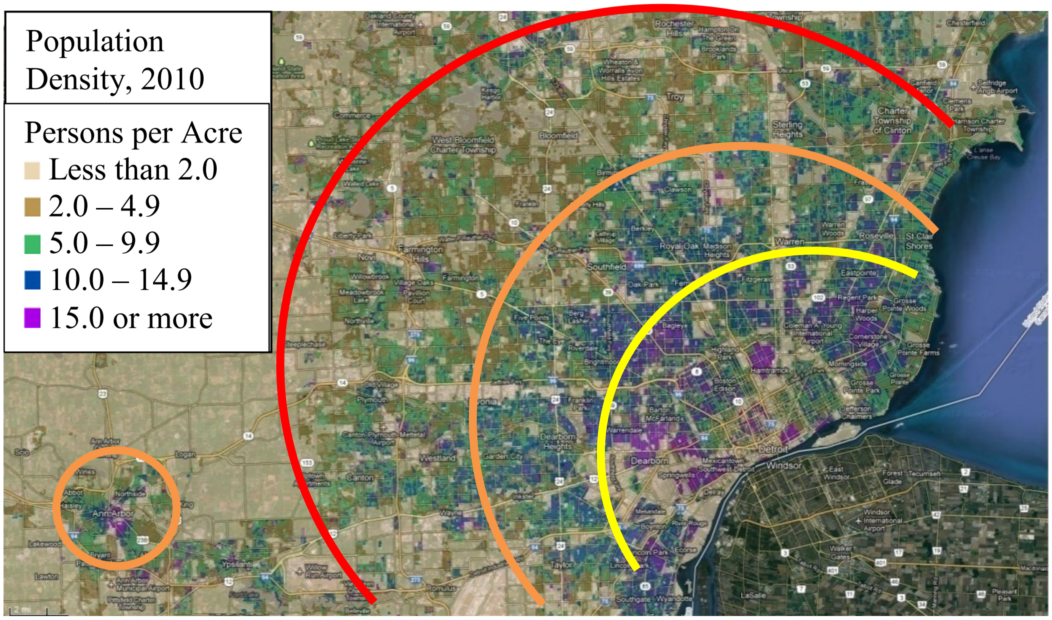
Figure 9: The Detroit Region/SEMCOG Jurisdiction

The six neighborhoods chosen (Figure 32) for this study fall within the jurisdiction of the Southeast Michigan Council of Governments (SEMCOG), which is referenced throughout the rest of this dissertation as the Detroit region. The 2000 Census data and objective land use neighborhood data (street networks and land uses) were used in the original neighborhood selection process. Traditional travel behavior studies have focused on generally robust and dynamic urban neighborhoods—characterized by higher densities, a mix of land uses, and high connectivity—and compared them to newer, suburban neighborhoods characterized by lower density, predominantly single-use neighborhoods with curvilinear street patterns.

The built environments selected for comparisons were generally upscale and dynamic and little focus was placed on trying to capture travel behavior among residents of lower income neighborhoods, which might be characterized by higher densities, mixed land uses, and connected street networks, but that might also be experiencing disinvestment and decline. Within the existing built environment and travel behavior literature, the relationship between socio-economic conditions (and particularly in neighborhoods experiencing urban decline and disinvestment), urban form and travel are recognized as underrepresented in urban research (USDHHS, 2000; Day, 2003; 2006; Vojnovic, 2006; Vojnovic et al., 2006; Vojnovic et al., 2013; Vojnovic et al, forthcoming; LeDoux and Vojnovic, 2013).

Four of the neighborhoods in this research focus on the traditional urban/suburban comparisons of generally wealthy and robust communities. Added to the mix are two lower income urban neighborhoods (higher density, mixed land use, and highly connected) that are experiencing disinvestment and decline. The two higher density and dynamic suburban neighborhoods are selected from the cities of Ann Arbor and Birmingham, the two lower density, and wealthy, suburban neighborhoods are selected from Bloomfield Hills and West Bloomfield, while the two poorer, higher density urban neighborhoods, experiencing disinvestment and decline, are selected from lower eastside Detroit.

Figure 10: Population densities in the SEMCOG Region



Source: www.semcog.org
* The yellow, orange and red arcs are drawn to show the decreasing levels of population density as visible on this map.

Figure 10 shows a map of the population densities within the SEMCOG region. The inner city Detroit neighborhoods were chosen for their built environments characteristics, high densities, grid street patterns (for high connectivity) and mixed land uses. This area also had a high concentration of black and lower income residents that either could not afford to move out of the city with the rest of the population exodus or they were prevented from moving due to racial discrimination practices. The urban Detroit neighborhoods are the two higher density mixed land use and connected neighborhoods experiencing disinvestment and decline. Moving out into the suburbs, Ann Arbor and Birmingham are chosen for their relatively high densities, mixed land uses and generally grid street patterns. These neighborhoods, while higher density, maintain higher socio-economic status. Bloomfield Hills and West Bloomfield are the neighborhoods in the last suburban typology grouping. They were chosen because they are representative of the low density suburbs that upper income groups move to who desire secluded and homogenous residential enclaves. These jurisdictions are characterized by low densities, curvilinear street patterns and mostly single land use neighborhoods and districts.

What follows is a description of each of the neighborhoods included in the study, along with their built environment objective characteristics. For the purposes of the analyses performed, the six neighborhoods were divided into three typologies, each consisting of two neighborhoods. The High Density Urban (HDU) typology, characterized by relatively high connectivity and mixed land uses, includes two neighborhoods from the City of Detroit. The High Density Suburban (HDS) typology, also characterized by relatively high densities, high connectivity and mixed land uses, includes a neighborhood from Ann Arbor and a neighborhood from Birmingham. The last typology is the Low Density Suburban (LDS) typology, neighborhoods that are characterized by low densities, low connectivity and generally single-use zoning, and includes a neighborhood from Bloomfield Hills and a neighborhood from West Bloomfield. For this chapter however, each neighborhood is discussed individually so as to give a detailed look at each of the six neighborhoods and how these characteristics prompted and facilitated the groupings into the three typologies.

The Inner-City Detroit Neighborhoods

Built Environment: Detroit

The two inner city Detroit neighborhoods depict a built environment that is typical of city layout of the late 19th and early 20th centuries. The street network is of a grid pattern, the density of structures is high, and there are mixed land uses scattered throughout the City. Not only the density of structures, but the population density is also high for a Michigan context, at 5,135 people per square mile for Detroit as a whole in 2010 (US Census, 2010). The “higher” density is relative to the built environment of the region, so the Detroit urban neighborhoods have a higher density than that of the areas surrounding the City. Connectivity, as measured by the number of 4-way intersections, is also high and that can be expected due to the gridiron street network.

Vacant homes are a big issue in the City, with 23% of the housing lying vacant in 2010, and the rest of the dwellings are evenly split between owner and renter occupied housing (SEMCOG, 2010). Home values are low in the City, with median home values in 2010 being $80,400 (a decline of 3% in the past decade) and median home rent in 2010 is $747 (an increase of 16.5% in the last decade) (US Census, 2010). A look at the 2008 land use information shows 41% of the land being used for single family residences (with an additional 2% being used for multi-family units) and 31% being used for transportation and utility uses. Other land uses have much smaller shares, and includes some 8% of land in industrial uses, and 6% each in institutional and park and recreation uses (SEMCOG, 2010).

Socio-Economic and Demographic Characteristics: Detroit

The 2010 Census showed that the City lost a quarter of its population within the last decade. A look at the absolute numbers show that the black population decreased by about 185,000, compared to a decrease of about 44,000 white residents. The black population has also started to move out of the City. Nevertheless, over 82% of the population in the City of Detroit was black in 2010, while just under 8% was white, showing a disproportionately high racial concentration of African Americans in the City (US Census 2010). A look at the educational attainment, from the 5 year American Community Survey in 2010, shows that the City has a small percentage—some 12% of the population—that has a bachelor's degree or higher (with only 4.6% having a graduate degree or higher), while 34% of the residents have only graduated high school, and another 23% have not graduated high school (US Census, 2010). This depiction of a large, poorly educated population is reflected in incomes as well. Median household income and per capita income decreased between 2000 and 2010 by 26.6% and 21.8% respectively. Consequently, the number of households and individuals living in poverty increased by 2% (to 30.8% of households) and 6.2% (to 34.5% of individuals) within the past decade (US Census, 2010). These facts depict the hollowing out of the city, and especially by the educated and the skilled. Middle and upper income groups have moved into the suburban areas, while the lower income groups, who consist predominantly of black residents, have remained within the city boundaries.

Travel Characteristics: Detroit

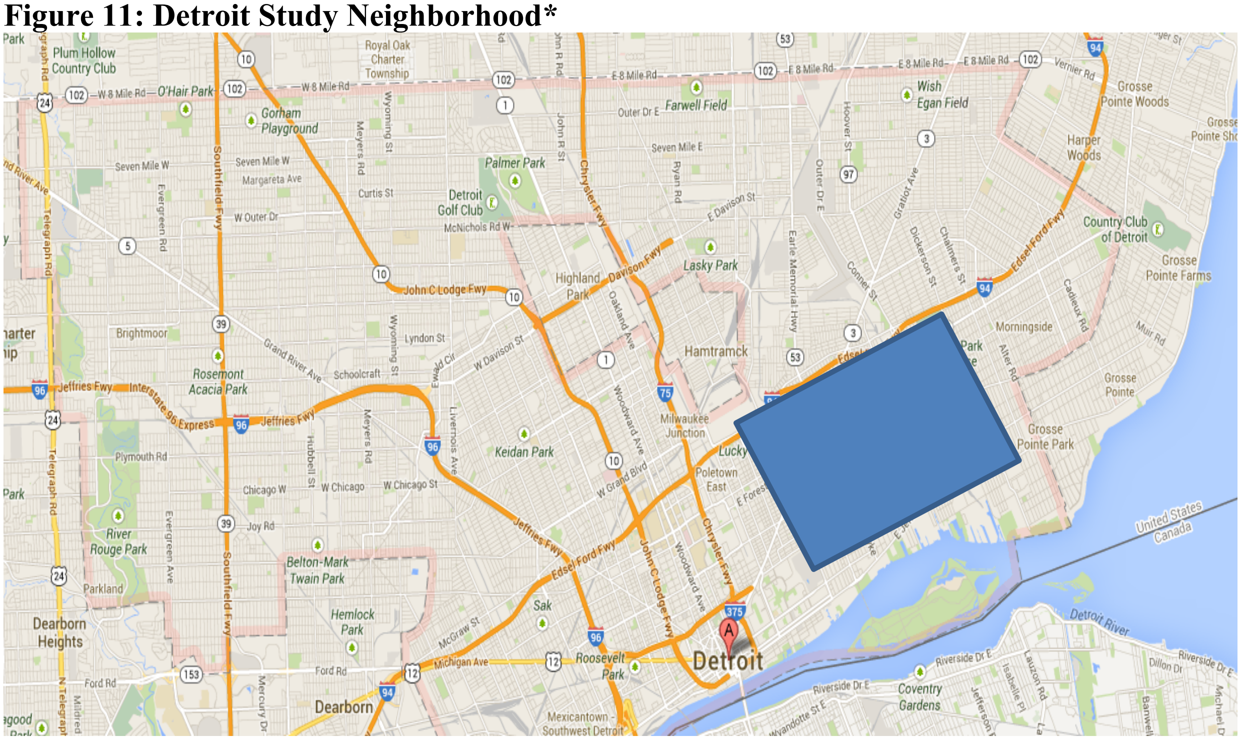
A note on travel characteristics that will be discussed in this section is warranted upfront. The below mentioned characteristics are from the 5 year American Community Survey in 2010. These numbers reflect the limited travel characteristics of journeys to work only and therefore are geared to a limited section of the full array of travel behavior that residents engage in on a daily basis. Similarly, the data itself is from a sample of the city-wide population and therefore is crude and limiting in nature. All of the particular distinctions in neighborhood travel characteristics are simply averaged out throughout the jurisdictional boundary. Detailed information and nuances that are inherent at lower scales of analysis, such as a neighborhood, are simply not available with this data.

A majority of the residents 16 years and over drove alone to work (73%), with an average travel time to work of about 26 minutes (US Census 2010). The use of car or van pooling and public transit decreased in the last decade, from 17% in 2000 to 11.5% in 2010. Only about 8% of the total working population use public transit to get to work. The City has two forms of public transit, an automated electric rail system (called the Detroit People Mover), and the much more extensive bus system run by the Detroit Department of Transportation (DDOT). The People Mover is an elevated rail line that encircles about 3 miles of the downtown Detroit area. This system is built to move people around the downtown, rather than to move people between home and work destinations. The bus system, on the other hand, is quite extensive. The DDOT has been the principal transit provider in the City since the mid-1970s. It has 48 bus routes serving Detroit and the surrounding communities (DDOT, 2010). Figure 12 shows the different routes served by DDOT buses.

Neighborhood Specifics: Detroit

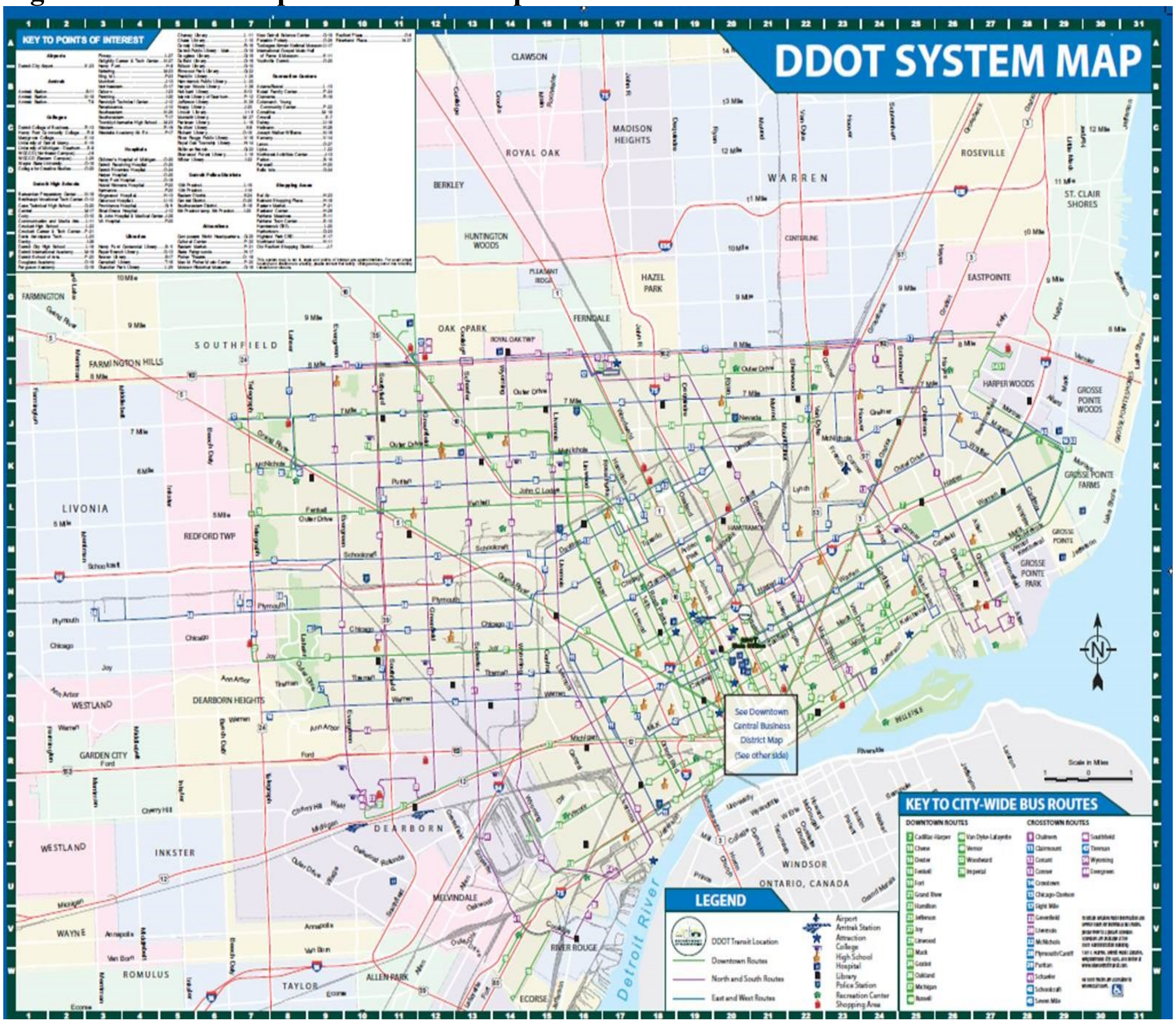
The study neighborhoods in this region are adjacent to each other and are located in the lower eastside of the City (see figure 11). For the first neighborhood, Highway I94 forms the northern border, Moran Street forms the western border, Kercheval Street is the southern border and Bewick Street is to the East. Gratiot Avenue is a major street that cuts through this neighborhood. The second neighborhood is bounded by I94 to the North, Philip Street to the East, Kercheval Street to the South and Harding Street to the West. Within this second neighborhood is a considerably large section of land that is industrial, as visible in the map of the neighborhood. Table 3 compares the population density of the City to those of the census tracts encompassing both the study neighborhoods for the 2000 and the 2010 Census years.

Figure 11: Detroit Study Neighborhood*



* The above map shows the general placement of the study neighborhoods within the City

Figure 12: Detroit Department of Transportation Bus Routes*



Source: Detroit Department of Transportation
* The lines show the prevalence of public transit in the City

The neighborhoods were initially selected using the 2000 Census figures, while the survey collection was completed towards the end of 2008. Therefore, data for both the 2000 and 2010 Census years are provided. It is fair to assume the actual density figures are closer to the 2010 Census data than to the 2000 data. The 2010 population density of each of the two neighborhoods was 4,162 and 3,644 people per square mile, showing a decline from the 2000 figures. Again, the Detroit 2 neighborhood has a large parcel of land dedicated to a Chrysler plant and therefore the density figures of this neighborhood are lower than the densities of the Detroit 1 neighborhood.

Table 3: Population density (per square mile) of Census Tracts Encompassing the Detroit Study Neighborhoods

	Detroit 1		*Detroit 2*		*Average High Density Urban Typology**	
	2000	*2010*	*2000*	*2010*	*2000*	*2010*
Density	6,896	4,162	5,627	3,644	6,314	3,928

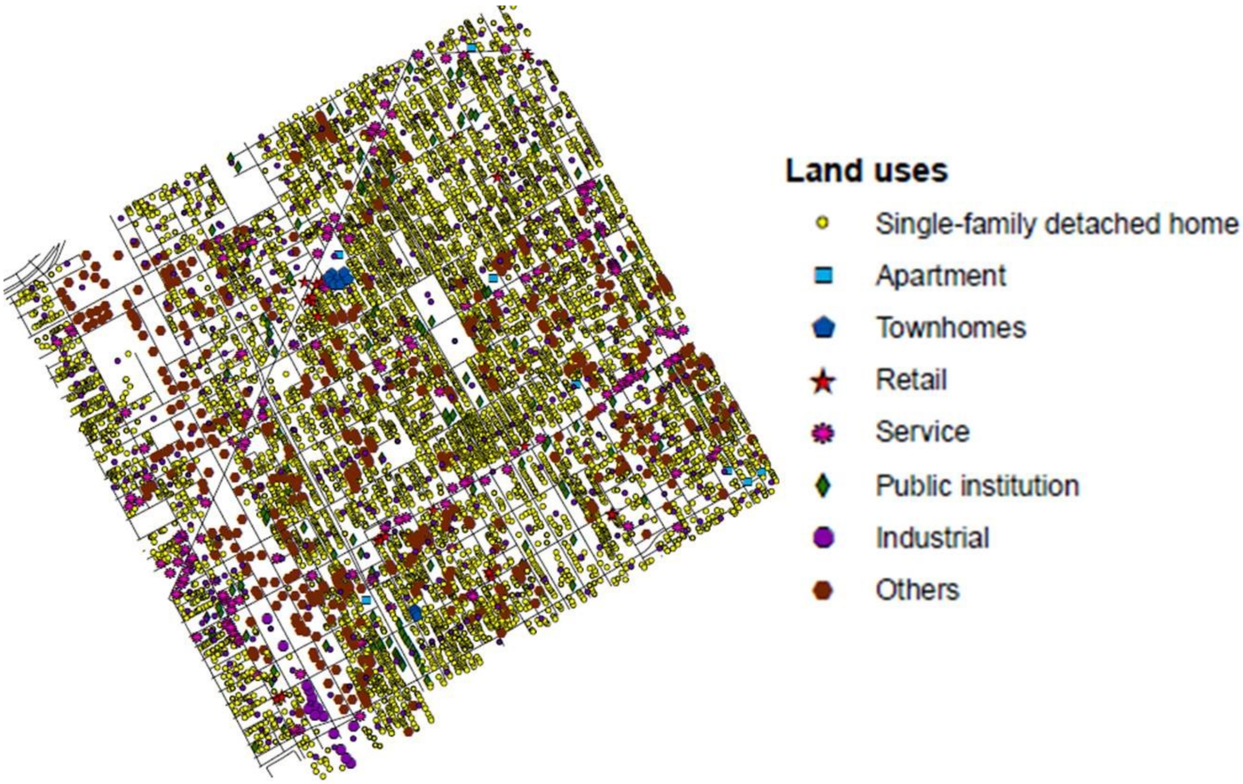
* If the Chrysler plant area is excluded, the average Urban Typology density for 2000 and 2010 would be 6,941 and 4,227 people per square mile respectively.

Objective land use data from neighborhood field surveys show that there is a mix of land uses-from residential, to commercial, to institutional—scattered throughout the neighborhoods. Figures 13 and 14 show the land use maps for the neighborhoods. The maps are a visual snapshot of the mix of land uses within each neighborhood. These maps also depict the relative lot sizes and compactness of the neighborhoods.

The number of 4-way intersections within each of the neighborhoods is 377 and 294. Since total length of road miles specifically within the neighborhoods is unavailable, the ratio of about 94 and 74 (for each of the 2 neighborhoods) 4-way intersections per square mile can be used to gauge the connectivity measures between neighborhoods. The HDU typology has the highest number of 4-way intersections among our six study neighborhoods.

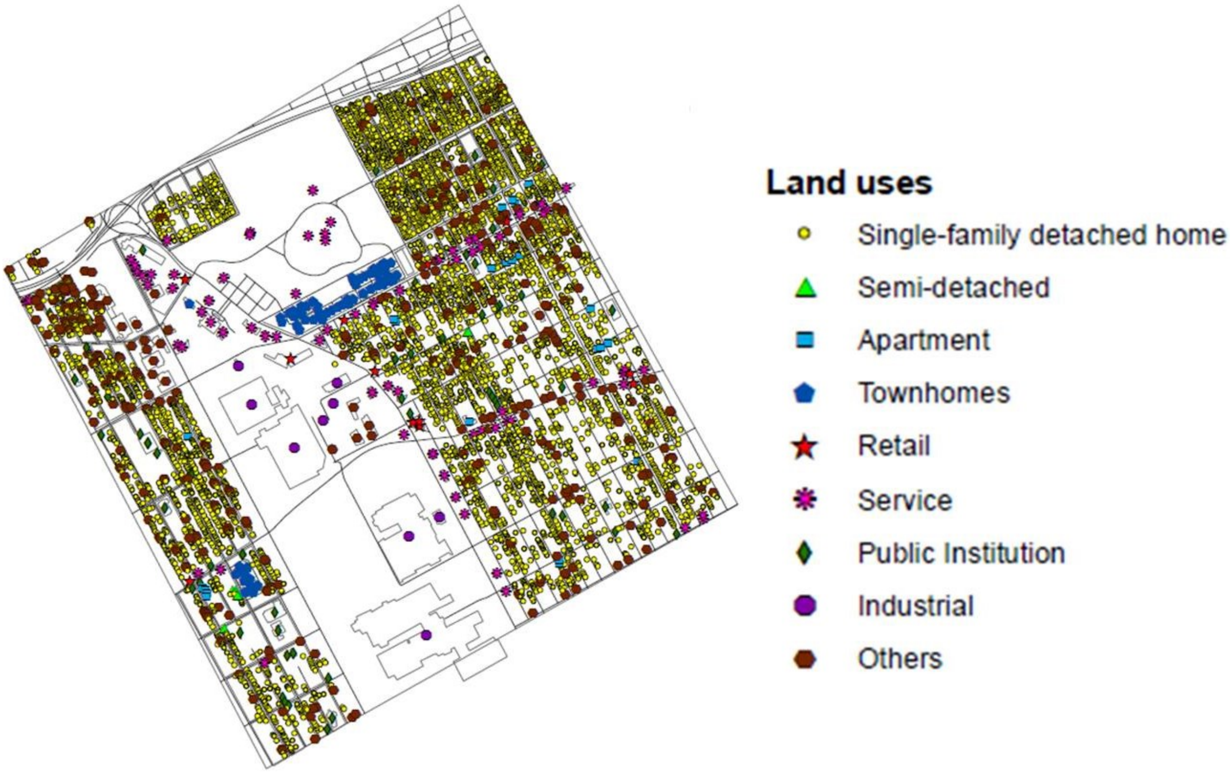
Lastly, the prevalence of public transit is shown through the number of bus stops within each neighborhood. The Detroit 1 and Detroit 2 neighborhoods have 176 and 144 bus stops respectively. These are scattered throughout the neighborhoods depicting an even distribution of public transit within this area.

Figure 13: Detroit Neighborhood 1 – Land Use Map*



*The above map shows the prevalence of various land uses within the study neighborhood (depicted by the different colors)

Figure 14: Detroit Neighborhood 2 – Land Use Map*



*The above map shows the prevalence of various land uses within the study neighborhood (depicted by the different colors)

Figure 15(a): Industrial Deterioration in Detroit

15(b): A Residential Street in the Detroit Study Neighborhood

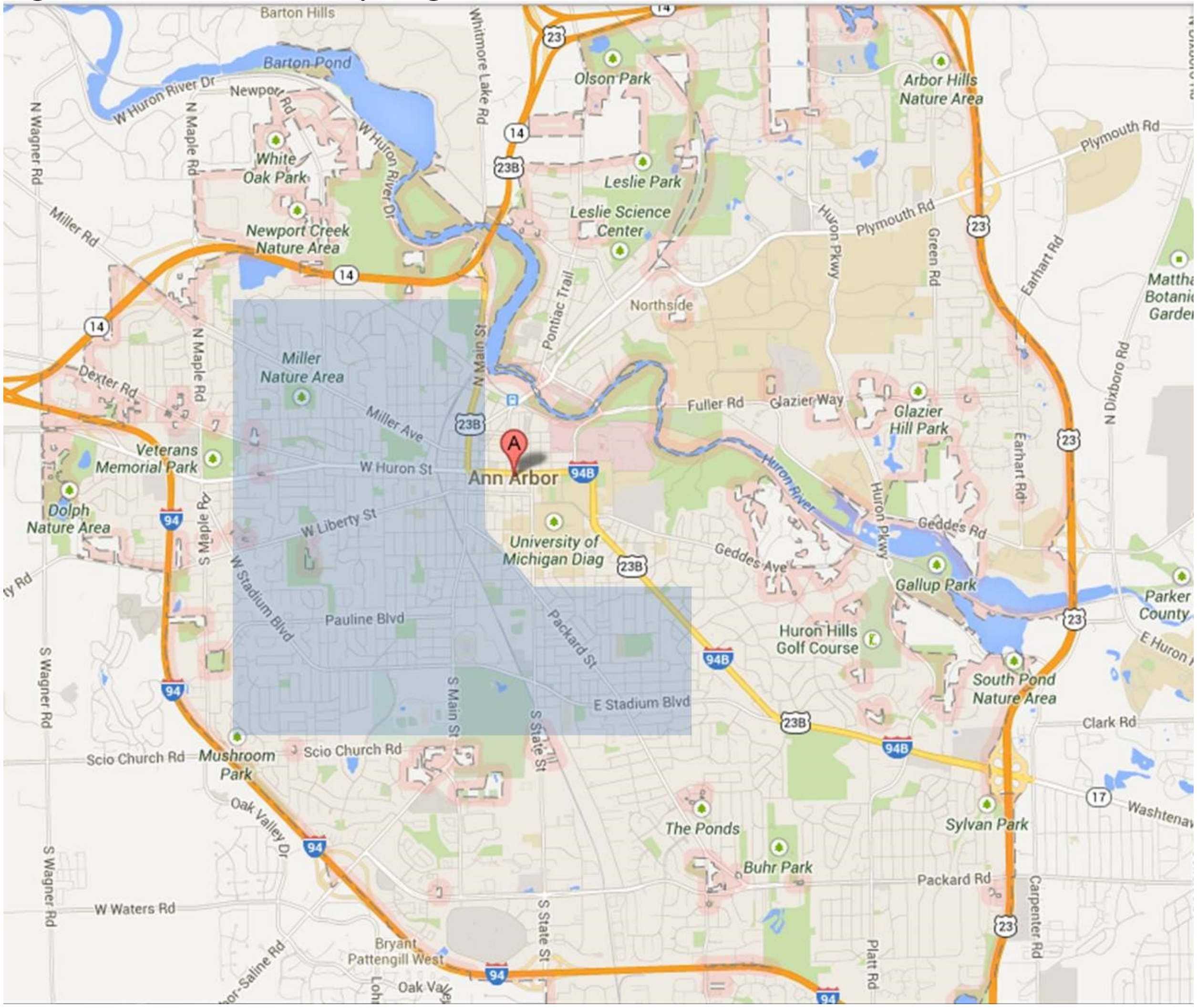
The Ann Arbor Neighborhood

Built Environment: Ann Arbor

According to the 2008 SEMCOG data, the City of Ann Arbor has an extensive mix of land uses. Some 41.6% of the land is allocated to residential uses (out of which 35.3% is for single family uses). Over 17% of the land is allotted to each government and institutional uses and to transportation and utility uses. Finally, 8% of the land is in commercial use, while another 2% of the land is in industrial use (SEMCOG, 2010). Population density for the City in 2010 was at about 4,128 persons per square mile, which is considered relatively high for the Michigan context (US Census, 2010).

There is an almost even split between the owner occupied and renter occupied housing units within Ann Arbor, with the former group representing 42% and the latter group representing 52% of the housing. Vacant houses account for only 5% of the housing stock (SEMCOG, 2010). The robust housing market is also reflected in the median home values. The median home value in 2010 was $240,400 while median rent was $946, with home values seeing a slight increase of 2% and rents seeing a slight decrease of 3.4% within the past decade (US Census, 2010). Figure 16 shows the map of the neighborhood within the City of Ann Arbor.

Figure 16: Ann Arbor Study Neighborhood*



* The above map shows the general placement of the study neighborhood within the City

Socio-Economic and Demographic Characteristics: Ann Arbor

The total population of Ann Arbor according to the 2010 Census was 113,934. This represents a miniscule decline in numbers from the 2000 Census of about 0.1%. Within the last Census decade (from 2000 to 2010), the percentage of non-Hispanic whites decreased from 72.8% to 70.4%, blacks decreased from 8.7% to 7.6%, and the Asian population saw the largest change, an increase from 11.9% to 14.3% (Census, 2010). Ann Arbor depicts a relatively diverse population and this can be attributed, in part, to the presence of the University of

Michigan within the City. The presence of the university is also evident in the educational attainment of the population. An overwhelming majority of 71% have a Bachelor's Degree or higher (with 42% having a professional or Graduate degree). In contrast, just 3% of the population did not graduate high school and 9% of the population were only high school graduates (US Census-ACS, 2010).

The median household income and per capita income were $52,625 and $30,498 respectively, a decrease of 13% and 12% between the 2000 and 2010 Census. Consequently, the number of persons and households living in poverty increased from 2000 to 2010, recorded as 20.2% and 17.7% respectively (US Census-ACS, 2010).

Travel Characteristics: Ann Arbor

Keeping in mind the limiting nature of the travel data from the American Community Survey, the following reflects the travel to work commute patterns of the Ann Arbor population. The number of people driving alone to work in Ann Arbor decreased by 4.3% between the 2000 and 2010 Census years and was recorded in 2010 at 58.4%. This group represented the majority of the resident working population. The second largest group was those who walked to work, at 15.5% of the working population, and this group saw a miniscule decline of 0.3% between the years 2000 and 2010. The numbers of those who used public transportation to get to work increased by 2.3%, to 8.9% of the working population, the third largest group among Ann Arbor's working population (US Census-ACS, 2010). These figures show a good mix of travel patterns being used by the resident population in Ann Arbor, although the automobile oriented nature of Ann Arbor residents clearly persists. The closer proximity of work destinations when compared to Detroit was evident in the median time taken to get to work, which was 18.8 minutes (US Census-ACS, 2010).

Ann Arbor's public transport system includes an extensive bus system run by the Ann Arbor Transportation Authority. The city does not have a rail transit system, except for the intercity Amtrak line. The bus system saturates the study neighborhood with about 160 bus stops within the 2 square mile neighborhood (AATA, 2012). Due to the relatively compact nature of the city, coupled with the high connectivity and accessibility measures, destinations are closer together and opportunities for travel via modes other than the automobile are extensive. Walking and bicycling, as well as using public transit, are modes that are utilized by residents for their daily travel needs. Overall, however, Ann Arbor is still generally an automobile oriented city. Figure 17 is a map of The Ride – The transportation system of the Ann Arbor Transportation Authority.

Figure 17: Ann Arbor Transportation Authority Bus Routes*

Source: The Ann Arbor Transportation Authority – The Ride
*The above map shows the prevalence of public transit in the City

Neighborhood Specifics: Ann Arbor

The neighborhood chosen for this study is a somewhat "L" shaped area, broadly bounded by M-14 highway to the north, Maple Road to the west, Scio Church Road to the south and Main Street and Ferndon Road to the east. This area encompasses the downtown region of the City as well as some of the University of Michigan campus in the southern part of the neighborhood. Looking at the population density figures, the City's overall density of 4,128 people per square mile is lower than that of the neighborhood, which stood at 5,427 in 2010. The main reason for this would be that the main core of the City is included within the study neighborhood and this is where a high concentration of residents are located.

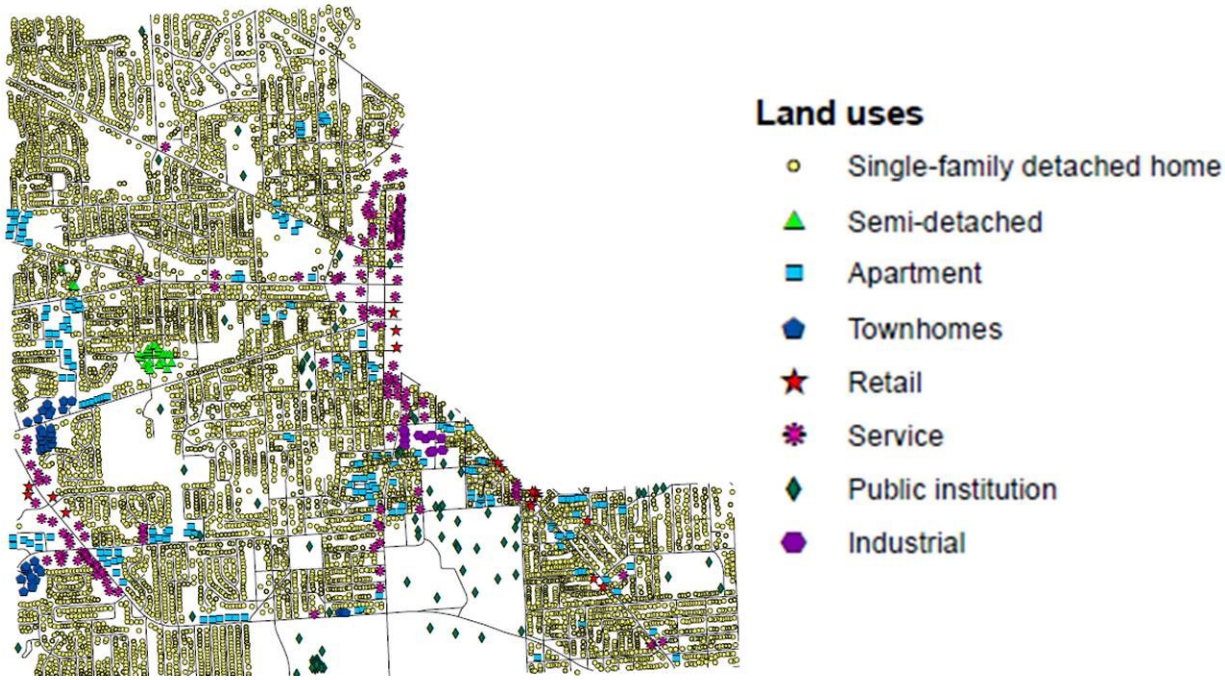
Table 4: Population density (per square mile) of Census Tracts Encompassing the Ann Arbor Study Neighborhood

	Ann Arbor		*Average High Density Suburban Typology**	
	2000	*2010*	*2000*	*2010*
Density	5,535	5,427	4,696	4,723

* The average refers to the combined figures for both neighborhoods in this typology.

A field survey of the neighborhood revealed an abundant mix of land uses, as evident in the Ann Arbor neighborhood land use map (Figure 18). The presence of the downtown area and the University of Michigan campus adds to the land use mix. This neighborhood has, more or less, a grid street pattern resulting in high connectivity and accessibility measures. The number of 4-way intersections within this neighborhood is 148. So, comparatively, this neighborhood has 62 4-way intersections per square mile, a drop from the figures for urban Detroit, but still a relatively high neighborhood connectivity.

Figure 18: Ann Arbor Neighborhood - Land Use Map*

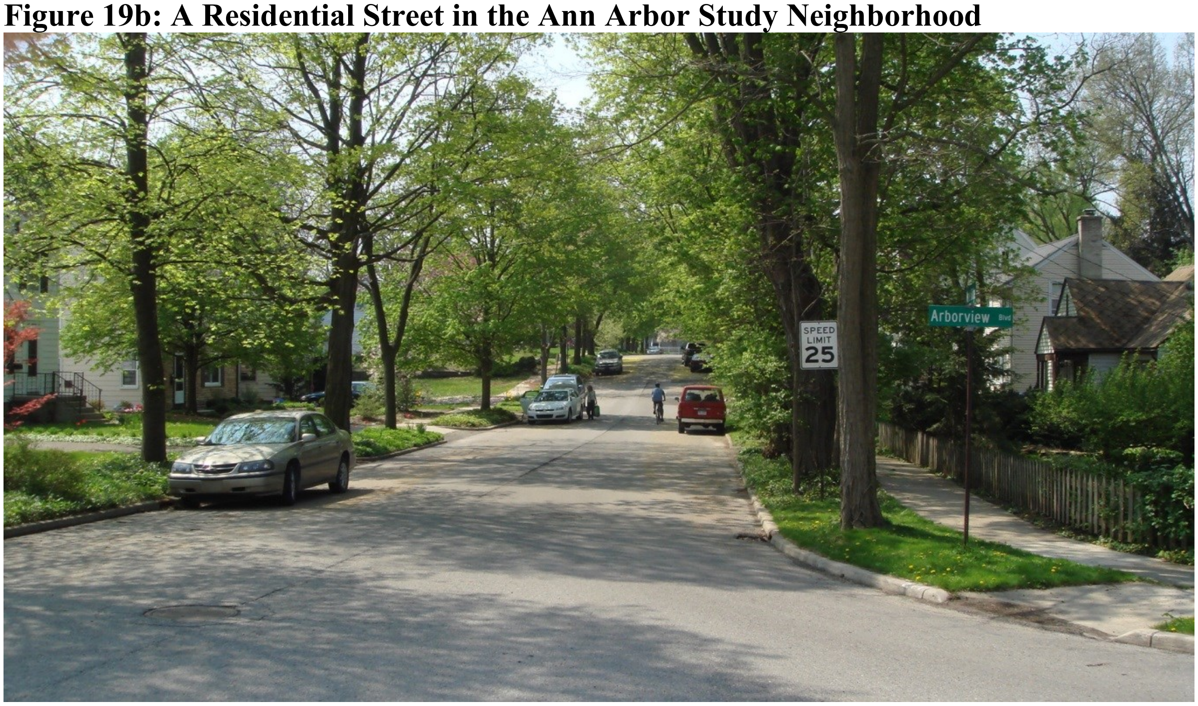


*The above map shows the prevalence of various land uses within the study neighborhood (depicted by the different colors)

With regard to mass transit, the AATA has an extensive bus system as the principle form of public transit in this neighborhood. This is revealed by the 160 bus stops that are located within the Ann Arbor neighborhood boundary. The number of bus stops in the Ann Arbor neighborhood is comparable to the urban Detroit numbers. Figures 19a and 19b show streetscapes in the Ann Arbor study neighborhood.

Figure 19a: Ann Arbor Main Street

Figure 19b: A Residential Street in the Ann Arbor Study Neighborhood



The Birmingham Neighborhood

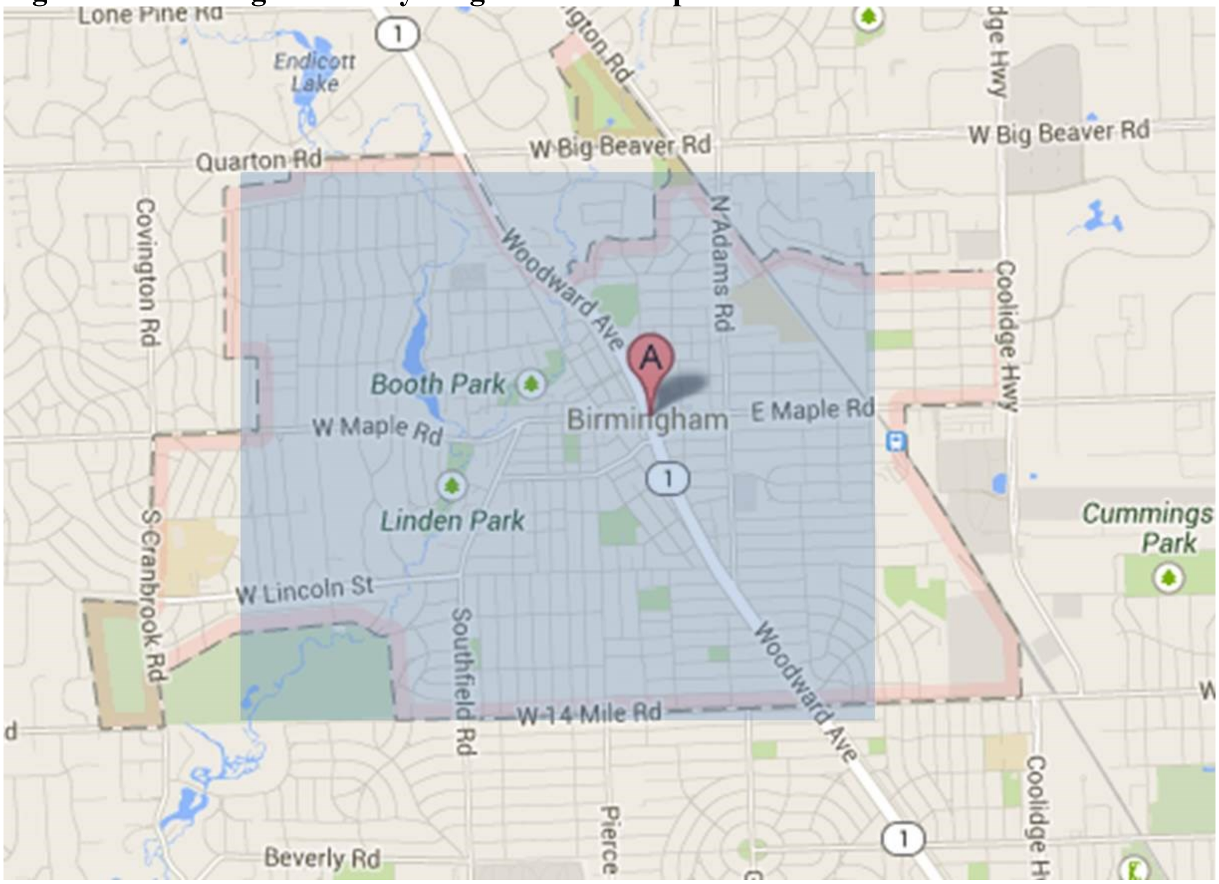
Built Environment: Birmingham

Birmingham is part of the inner ring suburbs of the Detroit region. It covers a small area of 4.8 square miles, and has a relatively high population density, some 4,188 people per square mile in 2010 (US Census, 2010). Street patterns are mostly gridiron, depicting a good measure of connectivity and accessibility. A major north-south street, Woodward Avenue, cuts through the City, with most non-residential uses concentrated on this main street. There is also a significant retail and commercial concentration along sections of the east-west streets, including Maple Road and Fourteen Mile Road. The small spatial extent of the City makes these commercial and retail strips 'accessible' to the residents of Birmingham.

A look at the 2008 land use information from SEMCOG shows that single family residences make up the majority of the land use, at over 52% of the total land use (with an additional 1% in multi-family units). A quarter of the land is taken up by transportation and utility uses, and institutional and park and recreation uses each take up a little over 7% of the land use. In Birmingham, industrial uses make up a mere 1% of the total land, while commercial uses make up less than 5% of the land use (SEMCOG, 2010).

Birmingham city's housing is predominantly owner occupied (66%), with only 9% of the housing lying vacant (US Census, 2010). Birmingham's robust housing market is depicted in its housing values, with the median home value and median rents at $369,200 and $1,191 respectively. Both of these values showed a decline of over 7% in the last decade (US Census-ACS, 2010).

Figure 20: Birmingham Study Neighborhood Map*



*The above map shows the general placement of the study neighborhood within the City

Socio-Economic and Demographic Characteristics: Birmingham

The City of Birmingham had a population of 20,103 people according to the 2010 Census, an increase of 4.2% over the 2000 Census population figures. This population is predominantly white (91%), while blacks and Asians make up 3% and 2.5% respectively of the city's population (US Census, 2010). Birmingham's residents have a high level of educational attainment, with 74% of the population having a bachelor's degree or higher, while 39% of the population has a graduate degree or higher. Only 6% of the population has just a high school degree and 2% of the population has not graduated from high school (US Census-ACS, 2010). As could be expected, the highly educated make-up of the population is also reflected in high incomes, with the median household and per capita incomes being $101,529 and $69,151 respectively. The City's predominantly white, highly educated and wealthy residents have few people and households living in poverty, at 3.8% and 4.8% respectively (US Census-ACS, 2010).

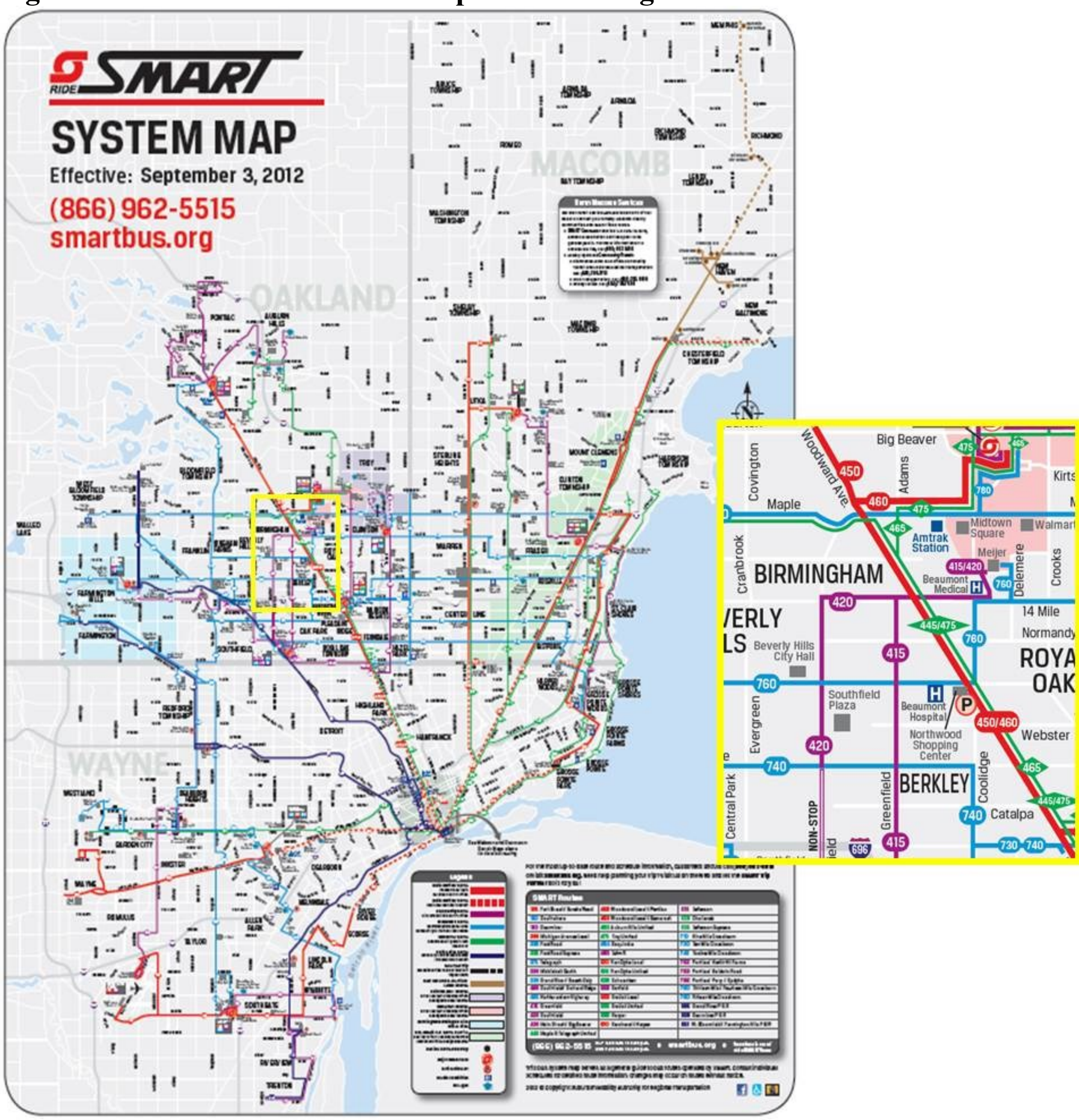
Travel Characteristics: Birmingham

As is evident from the built environment description, the main non-residential land uses are mostly along the major street, Woodward Avenue, and therefore there would be a very small percentage of the population who works and lives close enough to this street to be able to walk to work. There is no local rail public transport system, except for the inter-regional Amtrak station. There is also an absence of an extensive public transportation system within the City. The Suburban Mobility Authority for Regional Transportation (SMART) operates and runs a bus system within the area, but a closer look shows that this bus system reaches only the very few major roads within the City. Many people are thus relegated to drive to work despite the higher densities and high accessibility in the City of Birmingham.

The study neighborhood in Birmingham has many non-residential uses clustered along Woodward Avenue and this affects the travel patterns of the residents within the neighborhood. Looking at the full array of travel patterns, hence not only limited to work purposes, would depict a somewhat different travel behavior than what is depicted by the 5 year American Community Survey data. Notwithstanding, a look at the 2010 Census data on travel work patterns shows that a majority of the resident, working population drives alone to work (87.5%) with an average travel time of 22.8 minutes. Over 5% of the working residents worked at home.

Those who carpooled made up 3.4% of the working population, those taking public transit to work made up 0.2% of the working population and those who walked to work made up 2.5% of the resident working population (US Census-ACS, 2010). These facts depict the lack of an effective and extensive public transit system in a suburb, even a higher density suburb, where a large segment of the employment is located outside of the jurisdiction.

Figure 21: SMART Bus Routes Map with Birmingham Inset*



Source: Smart Bus Official Website (smartbus.org)
*The above map shows the "SmartBus" routes, and the inset map shows the prevalence of public transit in the City.

Neighborhood Specifics: Birmingham

The study neighborhood in Birmingham is bounded by Quarton Road to the north, Buckingham Road to the south, Westwood Road to the west and Eton Road to the east. With Woodward Avenue also cutting through the case study neighborhood, the street pattern, combined with the close proximity to this major arterial street, forms a highly connected street system with a mix of land uses in relatively close proximity. Knowing the 2010 City's population density to be at about 4,188 people per square mile, the density within the neighborhood comes in a bit lower, at 3,828 people per square mile. The presence of the main street, Woodward Avenue, and other non-residential strips within the neighborhood is the reason for the slightly lower density, since land uses on and around this avenue are mostly all commercial, retail and institutional. This is a case where the land use mix contributes to lower residential densities.

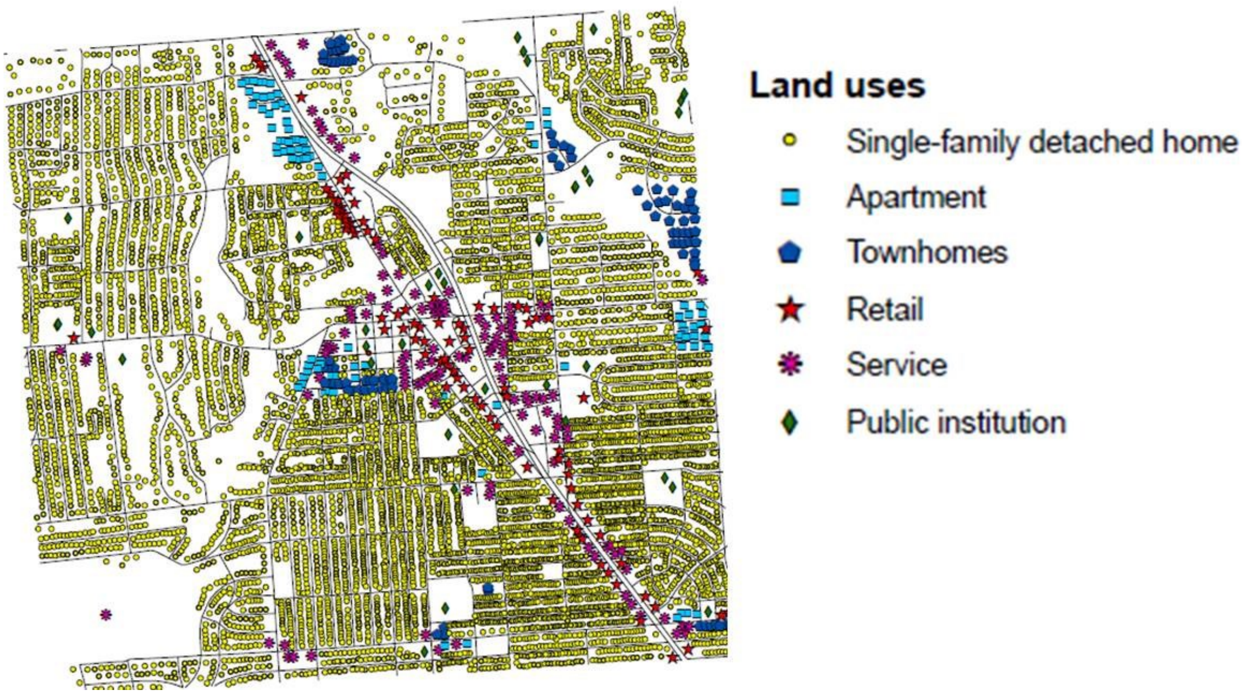
Table 5: Population Density (per square mile) of Census Tracts Encompassing the Birmingham Study Neighborhood

	Birmingham		*Average High Density Suburban Typology**	
	2000	*2010*	*2000*	*2010*
Density	3,630	3,828	4,696	4,723

* The average refers to the combined figures for both neighborhoods in this typology.

A look at the land use map, Figure 22, shows that most of the mixed land uses within this neighborhood and clustered along Woodward Avenue. There are some non-residential land uses scattered through the neighborhood (albeit, at a much lower level than the urban Detroit neighborhoods or even the Ann Arbor neighborhoods). Connectivity, as measured by the number of 4-way intersections, is also relatively high in this neighborhood. There are 217, 4-way intersections within the neighborhood, an average of about 54, 4-way intersections per square mile. This is lower than the counts for the urban Detroit neighborhoods, but still much higher than that for Ann Arbor, indicating that this region still has most of its road network in the gridiron pattern, promoting high connectivity.

Figure 22: Birmingham Neighborhood – Land Use Map*



*The above map shows the prevalence of various land uses within the study neighborhood (depicted by the different colors)

However, the neighborhood abundance in connectivity contrasts to its deficiency in access to public transit (See Figure 21). The Birmingham neighborhood has only 61 bus stops located within its boundaries. This number is significantly lower when compared to the number of bus stops in the Detroit and the Ann Arbor neighborhoods. This lack of alternative travel modes to the car is an important factor in shaping local travel patterns. Figures 23a and 23b show typical streetscape views of this neighborhood.

Figure 23a: Downtown Birmingham

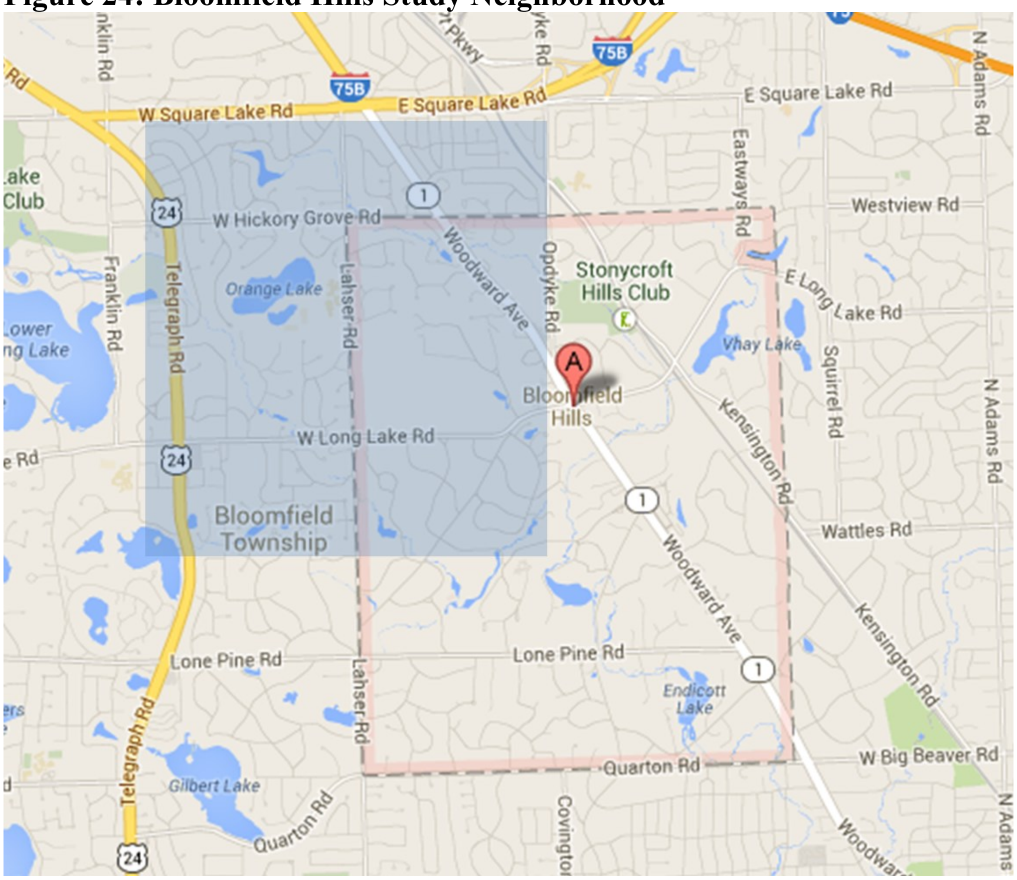
Figure 23b: Typical Birmingham Residential Street

The Bloomfield Hills Neighborhood

Built Environment: Bloomfield Hills

Moving to the low density suburbs, the City of Bloomfield Hills lies to the northwest of Birmingham and has almost the same spatial extent as the City of Birmingham, about 5 square miles, but it has less than one fifth of the population (3,869) of Birmingham. This results in the low population density of 774 people per square mile in this city (US Census, 2010). In Bloomfield Hills we also see a departure from the gridiron street network. Curvilinear streets dominate the landscape, with fewer 4-way intersections apparent in this city when compared to Detroit, Ann Arbor, or Birmingham.

Figure 24: Bloomfield Hills Study Neighborhood*

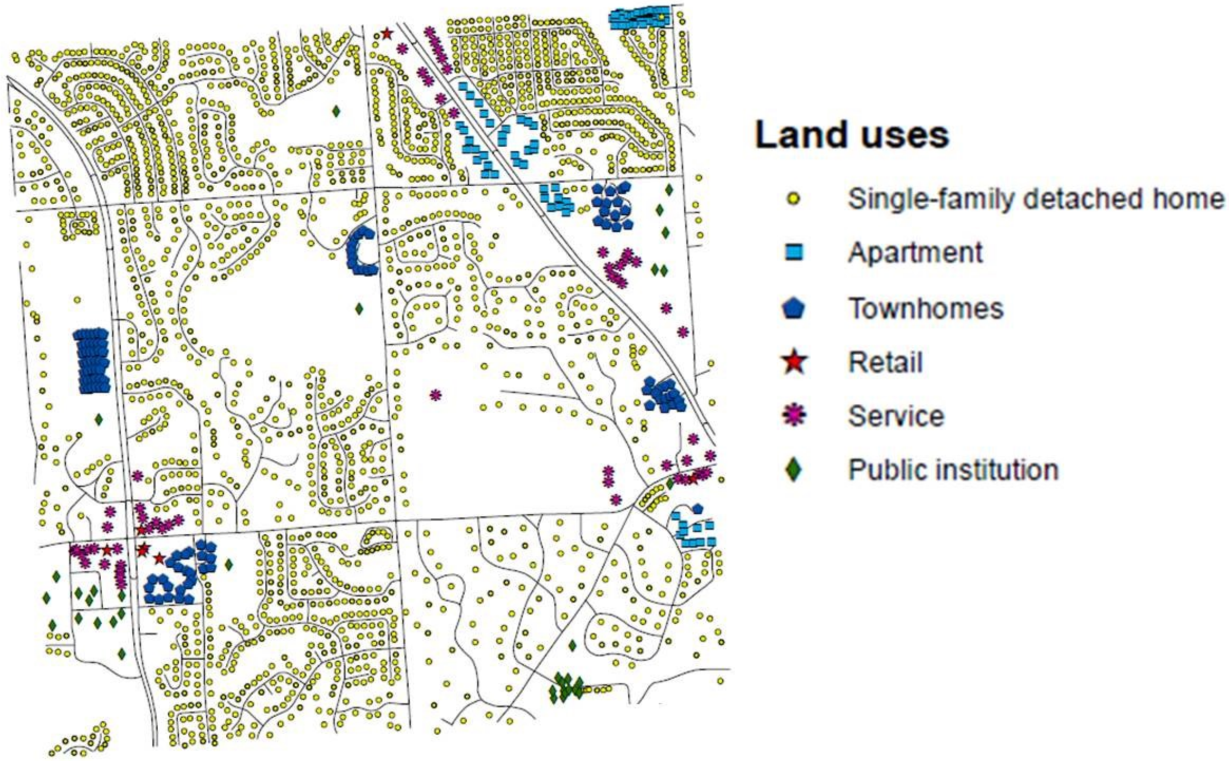


*The above map shows the general placement of the study neighborhood within the City

With respect to land uses, the SEMCOG 2008 data shows that over 61% of the land is used for single family housing, and there are no multi-family units in the City (SEMCOG, 2010). Two major streets cut through Bloomfield Hills, with Woodward Avenue running north-south and Long Lake Road running east-west. The commercial uses in Bloomfield Hills make up over 11% of the land area and are concentrated along these two major streets. The City houses the Cranbrook Institute of Science within the southern portion of its jurisdiction. Cranbrook is a renowned educational institution that houses a Pre-K through 12th grade prep school, an art museum, a graduate studies school, a science institute, and all within a 319-plus acre campus. This institution is the main reason that over 13% of the City's land use is classified as Government and Institutional. Transportation and utility make up some 12% of the City's land use. There is no industrial land in Bloomfield Hills and park and recreation space make up a miniscule 0.1% of land within this jurisdiction (SEMCOG, 2010). Probably the low densities, and hence large private lots, give residents enough private open space around their residences to not require any proximate public lands.

According to the 2010 Census figures, the vast majority of housing in Bloomfield Hills (81%) is owner occupied, while only 9% is renter occupied and about 10% of the housing stock in the City is vacant (US Census, 2010). The robust nature of the housing market is reflected in the house values. The median home value and gross rent is $715,300 and $747 respectively. About 37% of the owner occupied housing units are valued between $500,000 and $1,000,000, and another 32% of the housing units are valued at over $1,000,000 (US Census-ACS, 2010).

Figure 25: Bloomfield Hills Neighborhood – Land Use Map*



*The above map shows the prevalence of various land uses within the study neighborhood (depicted by the different colors)

Socio-Economic and Demographic Characteristics: Bloomfield Hills

The City of Bloomfield Hills had a population of 3,869 according to the 2010 Census, a drop of about 1.8% from the previous decade. This City is predominantly white (over 86%), while blacks and Asians made up 4% and 6.7% of the population respectively (US Census, 2010). Over 69% of the population has a bachelor's degree or higher (with 37.7% having a graduate degree or higher). Only 2% of the population did not graduate from high school. Those graduating high school and those having an associate's degree made up 15% and 14% of the population respectively (US Census, 2010). The median household and per capita incomes were

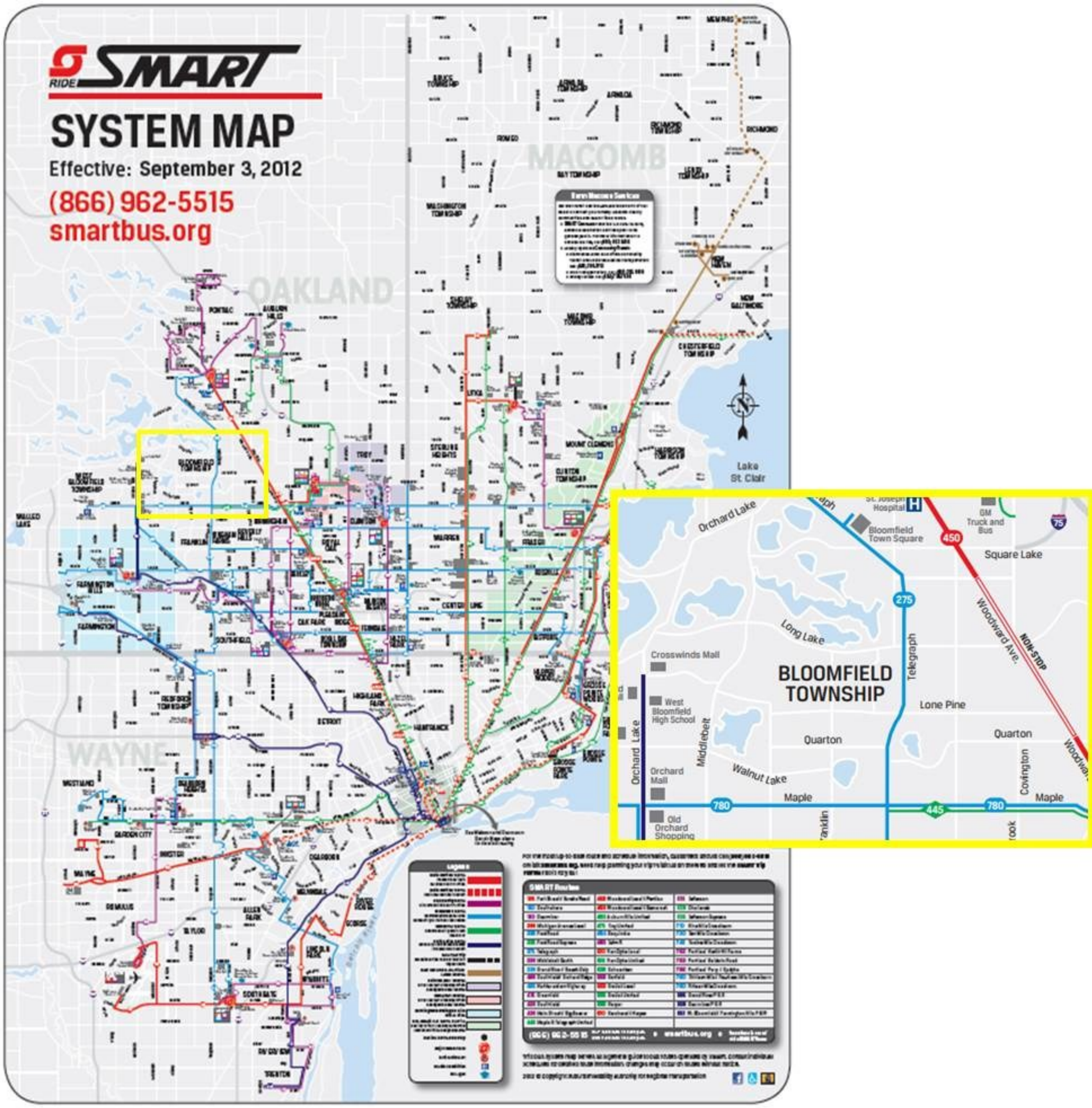
$133,370 and $89,538, much higher than that for Birmingham City, a jurisdiction that maintains a more polarized educational achievement (US Census-ACS, 2010).

Travel Characteristics: Bloomfield Hills

Travel patterns to work for the residents in the City are dominated by driving, with the average travel time to work in 2010 being about 23 minutes (US Census-ACS, 2010). Over 77% of the resident working population drives alone to work and another 11.5% carpools. In Bloomfield Hills, 10% of the population works from home, which in total makes up over 98.5% of the resident working population. No one takes public transportation and only 1% of the working population walked to work (US Census-ACS, 2010). What is absolutely clear is the total dependence on the automobile for travel purposes. Over 10% of the resident population travels to Detroit for work, while less than 6% of the workers in the City are actually Detroit residents.

There is no public transportation, rail or bus, within the City. The SMART bus system just reaches the southern edge of the City (see Figure 25). Lack of connectivity and the relegation of the relatively few and scattered commercial uses to the two main streets make walking for daily travel needs extremely difficult. In addition, the lack of mass transit makes public transportation non-existent.

Figure 26: SMART Bus Routes Map with Bloomfield Hills Inset*



*The above map shows the “SmartBus” routes, and the inset map shows the prevalence (rather the lack of) of public transit in the City.

Neighborhood Specifics: Bloomfield Hills

The Bloomfield Hills study neighborhood is bounded by Square Lake Road to the north, Lone Pine Road to the south, Opdyke Road to the east and Franklin Road to west. The neighborhood is typical of the City, with the two main streets, Woodward Avenue and Long Lake Road passing through the eastern and southern section of the neighborhood respectively. Looking at the population density of the study neighborhood, it is higher than that of the City of Bloomfield Hills, with the 2010 neighborhood density being 1,141 people per square mile (compared to 774 people per square mile for the City). This can largely be attributed to the presence of the Cranbrook Institute in Bloomfield Hills, which is only partially included towards the southern border of the neighborhood.

Table 6: Population density (per square mile) of Census Tracts Encompassing the Bloomfield Hills Study Neighborhood

	Bloomfield Hills		*Average Low Density Suburban Typology**	
	2000	*2010*	*2000*	*2010*
Density	1,175	1,141	1,797	1,711

* The average refers to the combined figures for both neighborhoods in this typology.

Connectivity measures are low; the lowest within this built environment typology. The neighborhood has 33, 4-way intersections, an average of 8 intersections per square mile. This number is very low compared to the other two neighborhood typologies discussed earlier. The predominance of curvilinear streets reduces connectivity. The neighborhood is almost predominantly residential, making accessibility to out-of-home destinations weak. With very few destinations and other non-residential uses in close proximity, coupled with the curvilinear street network, driving is the mode of travel that the residents are forced to take. Adding to the predominance of private automobile use is the fact that there are only 15 bus stops within this neighborhood. As mentioned earlier, the SMART bus system reaches only the edges of the City and ultimately provides a weak alternative to private vehicle travel. Figures 27a and 27b depict typical streetscape views of this neighborhood.

Figure 27a: Typical Bloomfield Hills Residential Street

Figure 27b: Typical Bloomfield Hills Residential Neighborhood

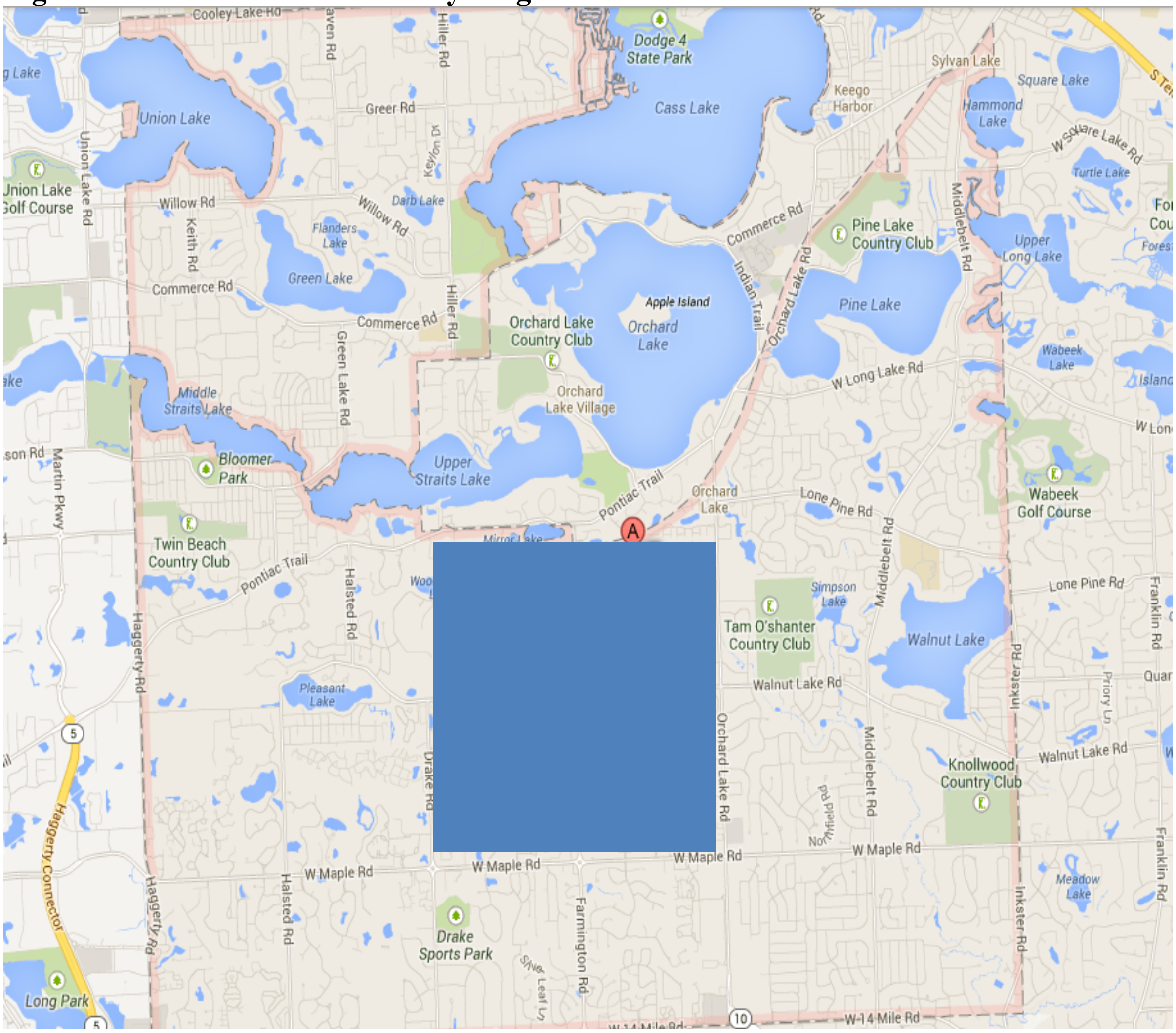
The West Bloomfield Neighborhood

Built Environment: West Bloomfield

The Charter Township of West Bloomfield lies to the west of the City of Bloomfield Hills. The Township is larger in spatial terms, covering about 31.3 square miles (US Census, 2010). Again, this is a second ring suburb of the Detroit Region and typical of its age, it lacks a grid street pattern. The streets are generally curvilinear, leading to low connectivity. The population according to the 2010 Census was 64,690, resulting in a density of about 2,066 people per square mile (US Census, 2010).

The 2008 land use information from SEMCOG indicates that the Township had 56.4% of its land in single family residences (with only an additional 2% of land devoted to multi-family units). There are quite a few lakes in the northern section of the Township, and therefore water makes up about 14.7% of the land use. Transportation and utility uses make up 13.4% of the land, while industrial uses make up a mere 0.6% and commercial uses another 3.7% of the land. Parks and open space make up about 5% of the land, with quite a few golf courses located within this township. Government and institutional uses make up another 4% of the total land in the Township, with many churches and schools located within the jurisdiction (SEMCOG, 2010). Non-residential uses are clustered along the main streets of Orchard Lake Road (north-south street), Walnut Lake Road, and West Maple Road (both east-west streets).

Figure 28: West Bloomfield Study Neighborhood*



*The above map shows the general placement of the study neighborhood within the Township

Housing conditions depict a robust community, with over 77% of the housing units being owner occupied, 16% being renter occupied, and only 7% lying vacant in 2010 (US Census, 2010). Median home and rent values reflect the socio-economic composition of this jurisdiction, with 2010 median home value being $291,200 and 2010 median rent being $1,425 (US Census-ACS, 2010). Home values are lower than in Bloomfield Hills, however the rents are higher in

West Bloomfield. The largest percentage of owner occupied homes, over 30% of the housing, maintains values between $300,000 and $500,000 (US Census-ACS, 2010).

Socio-Economic and Demographic Characteristics: West Bloomfield

The 2010 Census put the population of the Township at 64,690, showing a minor decline of about 0.3% people within the last decade. The Township is still largely populated by white residents, making up 76.5% of the total population (a drop of about 6.7% over the previous decade). The black population, on the other hand, makes up about 11.3% of the total residents (showing an increase of 6.2% since the previous decade). The Asian population has been relatively stable between the two decades, at about 8.4% of the total residents (US Census, 2010). These figures show a steady influx of Black residents into the Township between 2000 and 2010, allowing a growing racial mix in this traditionally white community.

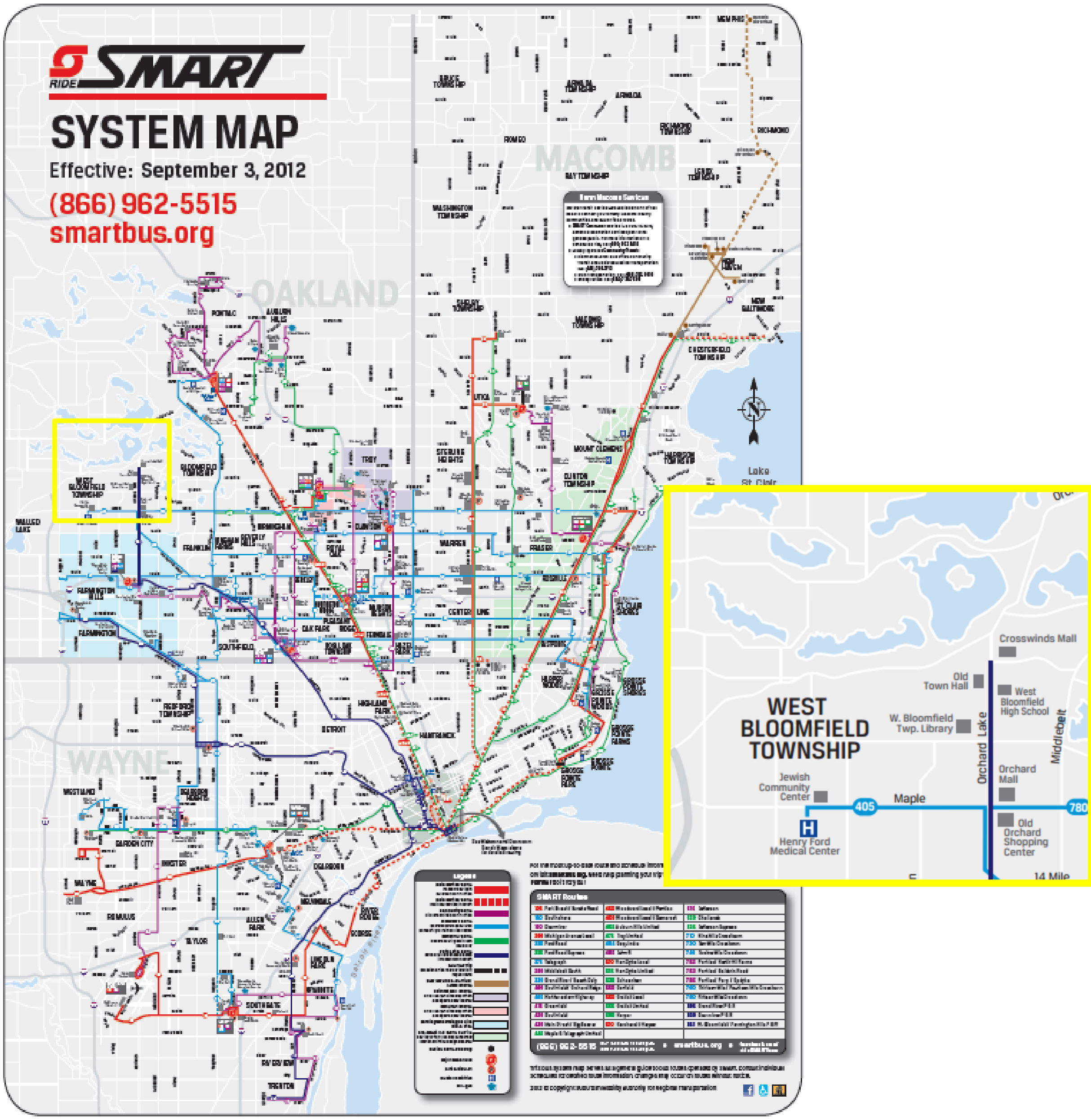
Looking at the educational attainment of the residents in West Bloomfield, some 55% of the population has a bachelor's degree or higher (with 25.6% having a graduate degree or higher). About 6% of the population has not graduated high school and another 15% are only high school graduates (US Census, 2010). Again, we see here a lower polarization among the resident population when compared to the City of Bloomfield Hills, and that can be attributed partly to the fact that we are now looking at the Charter Township of West Bloomfield, an area much larger than Bloomfield Hills City. The educational attainment data is reflected in the median incomes as well. The median household and per capita income was $97,004 and $47,201 respectively. In this township, 4% of the population and 4.2% of the households lived in poverty (US Census-ACS, 2010).

Travel Characteristics: West Bloomfield

West Bloomfield Township, like the City of Bloomfield Hills, has no effective public transportation system. There is no rail transit service and the SMART bus system reaches only the peripheral areas of the Township (see Figure 29). The built environment characteristics encourage travel by automobiles more than any other means. Census 2010 figures indicate that over 88% of the resident working population in the Township drove alone to work, while only 5.8% carpooled. The average travel time to work was about 28 minutes. Another 4.5% of the townships working population worked from home. Those taking public transportation to work made up a mere 0.2% and those walking to work consisted of 0.8% of the total resident working population (US Census-ACS, 2010).

The 2010 5-year American Community Survey data also shows that over 10% of the resident working population traveled to Detroit for work purposes, whereas over 6% of the workers in the Township came in from Detroit to work in the Township of West Bloomfield. Overall, the local travel characteristics show a dependence on automobile travel for a majority of work travel purposes. Public transit is not available and walking as a means of travel is difficult due to the lack of connectivity in the street network and a lack of access to proximate work destinations.

Figure 29: SMART Bus Routes Map with West Bloomfield Inset



*The above map shows the "SmartBus" routes, and the inset map shows the prevalence (rather the lack of) of public transit in the Township.

Neighborhood Specifics: West Bloomfield

The study neighborhood within the Township is bordered by Pontiac Road to the north, Maple Road to the south, Drake Road to the west and Orchard Lake Road to the east. A large part of the northern section of the neighborhood has open space and that is due to the presence of a number of golf courses in the area. The 2010 population density for the Township, at 2,066 people per square mile, is a bit lower than that of the neighborhood, which stood at 2,686 people per square mile. This is largely attributable to the larger amounts of open space within the Township, which is only partially included within the study neighborhood. The population density within this neighborhood is higher than that of Bloomfield Hills, however, these population density figures are much lower than those in the other two neighborhood typologies, the higher density urban and higher density suburban neighborhoods.

Table 7: Population density (per square mile) of Census Tracts Encompassing the West Bloomfield Study Neighborhood

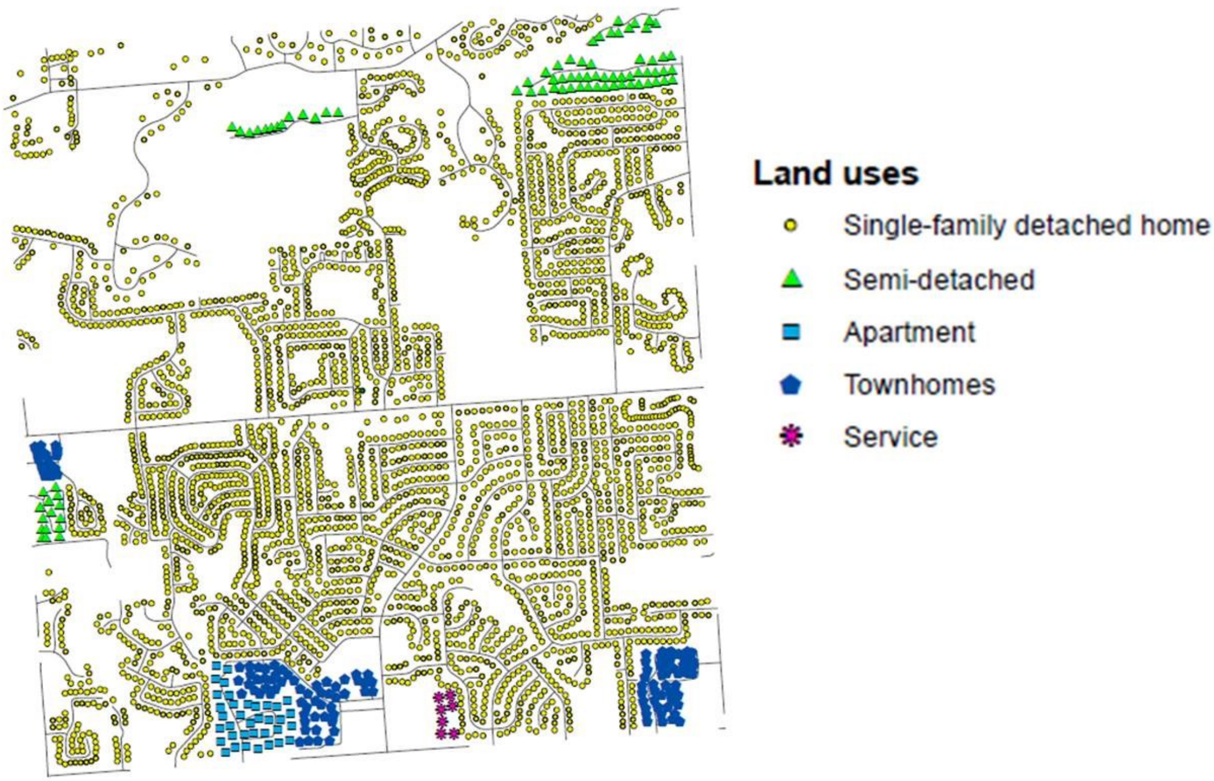
	West Bloomfield		*Average Low Density Suburban Typology**	
	2000	*2010*	*2000*	*2010*
Density	2,860	2,686	1,797	1,711

* The average refers to the combined figures for both neighborhoods in this typology.

This neighborhood also depicts spatial structure patterns that are similar to Bloomfield Hills. A predominance of curvilinear streets reflects low connectivity measures. There are only thirty, four-way intersections within the neighborhood, an average of 8 per square mile, the same as that of Bloomfield Hills. These are typical built environment characteristics of low density suburbs, where gridiron street patterns are almost non-existent. The land use map below (Figure

30) also shows the preponderance of residential land uses within this study neighborhood, with only a handful of "personal service" land uses at the southern edge of the neighborhood. Similar to Bloomfield Hills, this neighborhood also has 17 bus stops within its boundaries, escalating the effects of the low connectivity, low accessibility measures that encourage automobile use for travel. Figures 31a and 31b depict typical streetscape views of this neighborhood.

Figure 30: West Bloomfield Neighborhood – Land Use Map



*The above map shows the prevalence of various land uses within the study neighborhood (depicted by the different colors)

Figure 31a: Typical West Bloomfield Residential Neighborhood

Figure 31b: Typical West Bloomfield Residential Street

Commentary

The above description of the study area and neighborhoods show a variation in the socio-economic, demographic and built environments captured in the six neighborhoods. All the neighborhoods are approximately 4 square miles in area, and have been chosen so that an effective analysis can be completed, distinguishing between typical higher density and lower density urban forms, but also adding a higher density urban built environment characterized by disinvestment and decline. As mentioned earlier, traditional analyses on travel behavior has generally focused on robust communities. The inclusion of a neighborhood that is typical of a high density, high connectivity and high accessibility area, but experiencing severe disinvestment, has not been the focus of travel behavior studies. The six neighborhoods included in this research will cover an important gap in the travel behavior research and will add insight into the travel behavior of residents living in neighborhoods of rapid decline.

The next chapter will discuss the data gathered and analyzed in this dissertation. Although a general description of the communities and the study neighborhoods have been provided in this chapter, a more detailed review of the data will be provided in Chapter V. The chapter will also develop the research objectives, questions, hypotheses and will include the methodology of the quantitative analysis into travel behavior and environmental burdens (gasoline consumption and CO emissions).

Chapter V - Research Hypotheses, Data, and Methodology

Introduction

This chapter begins by laying out the research hypotheses for this study. In particular, travel behavior and the resulting environmental burdens (measured by CO emissions and fuel consumption) are being tested to see if they have any significant associations with the socio-economic characteristics of residents in study neighborhoods that have differing built environment characteristics. Following the hypotheses, the next section in this chapter focuses on the data collected for this study. The data is a combination of primary data, collected through a mail survey, as well as secondary data from the Michigan Secretary of State and the Environmental Protection Agency. The last section in the chapter discusses, in detail, the methodology that was adopted to test the hypotheses and to enrich the understanding of what this rich dataset has to offer to this line of research. The methodology ranges from Discriminant Analysis to see the differ impacts that the built environment has on travel behavior and environmental burdens, to Cluster Analyses to objectively discern the clusters/groups that the data was lending itself to. As researchers, we have a predetermined idea of what the data might indicate. A Cluster Analysis gives strength to that thought, in the sense that it adds to the detail that helps form certain groups of observations. The last set of analyses performed were the Regressions, which are conducted to test and answer the hypotheses and research question.

This dissertation explores the following general hypothesis:

Socio-economic characteristics and built environment conditions have a significant impact on environmental burdens as related to gasoline consumption and pollutant emissions

The analyses span six Detroit region neighborhoods. Research at the neighborhood level would fill a void in current studies where density and socio-economic characteristics have not been combined to tease out the nuances of travel behavior as related to gasoline consumption and pollutant emissions. The unique aspect here is the marrying of the built environment, socio-economic factors and travel patterns at the neighborhood scale, along with the associated fuel consumption and vehicular emissions. The following research question would aid in understanding and assessing the main hypothesis. The research question, in turn, is presented with sub-hypotheses.

Research Question

Do socio-economic characteristics of residents, by neighborhood type, significantly impact travel patterns, gasoline consumption and vehicular emissions?

Objective

To explore the relationships between socio-economic characteristics and vehicular trips, along with associated gasoline consumption and pollutant emissions, for different trip purposes by neighborhood typology. For purposes of this research question, neighborhood types are categorized into higher density urban (HDU), higher density suburban (HDS), and lower density suburban (LDS) neighborhood typologies, and trip purposes are categorized into work, non-work, and all trips combined. The categorization of the six neighborhoods into three 'neighborhood typologies' will be discussed in the Methodology section of this chapter.

Hypotheses

Mode of Travel

a) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics will travel more often by *private vehicles* (measured as a percentage of total trips traveled by car) than their counterparts with lower socio-economic characteristics.

b) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics travel less frequently by *public transit* (measured as a percentage of total trips traveled by public transit) than their counterparts with lower socio-economic characteristics.

c) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics travel less often by *walking/biking* (measured as a percentage of total trips traveled by walking/biking) than their counterparts with lower socio-economic characteristics.

Total Miles Traveled

d) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics will travel more miles annually by *private vehicles* (thereby consume more fuel and emit more pollutants) than their counterparts with lower socio-economic characteristics.

e) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics will travel fewer miles annually by *public transit* than their counterparts with lower socio-economic characteristics.

f) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics will travel fewer miles annually by *walking/biking* than their counterparts with lower socio-economic characteristics.

Vehicle Ownership & Characteristics

g) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics own *newer vehicles* than their counterparts with lower socio-economic characteristics.

h) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics own *more vehicles per household* than their counterparts with lower socio-economic characteristics.

i) Within each neighborhood type (HDU, HDS, and LDS), residents with higher socio-economic characteristics own *vehicles with larger engines* than their counterparts with lower socio-economic characteristics.

OLS Regression Model:

$$\text{DEPENDENT VARIABLE} = \alpha + \beta_1 \text{PERSONAL/HOUSEHOLD INCOME} + \beta_2 \text{ EDUCATION} + \beta_3 \text{ OCCUPATION} + \varepsilon$$

The Dependent Variable would be Travel Mode (Hypotheses a, b, c), Total Miles Traveled (Hypotheses d, e, f), Vehicle Age (Hypothesis g), Number of Vehicles per Household (Hypotheses h), and Vehicle Engine Size (Hypotheses i).

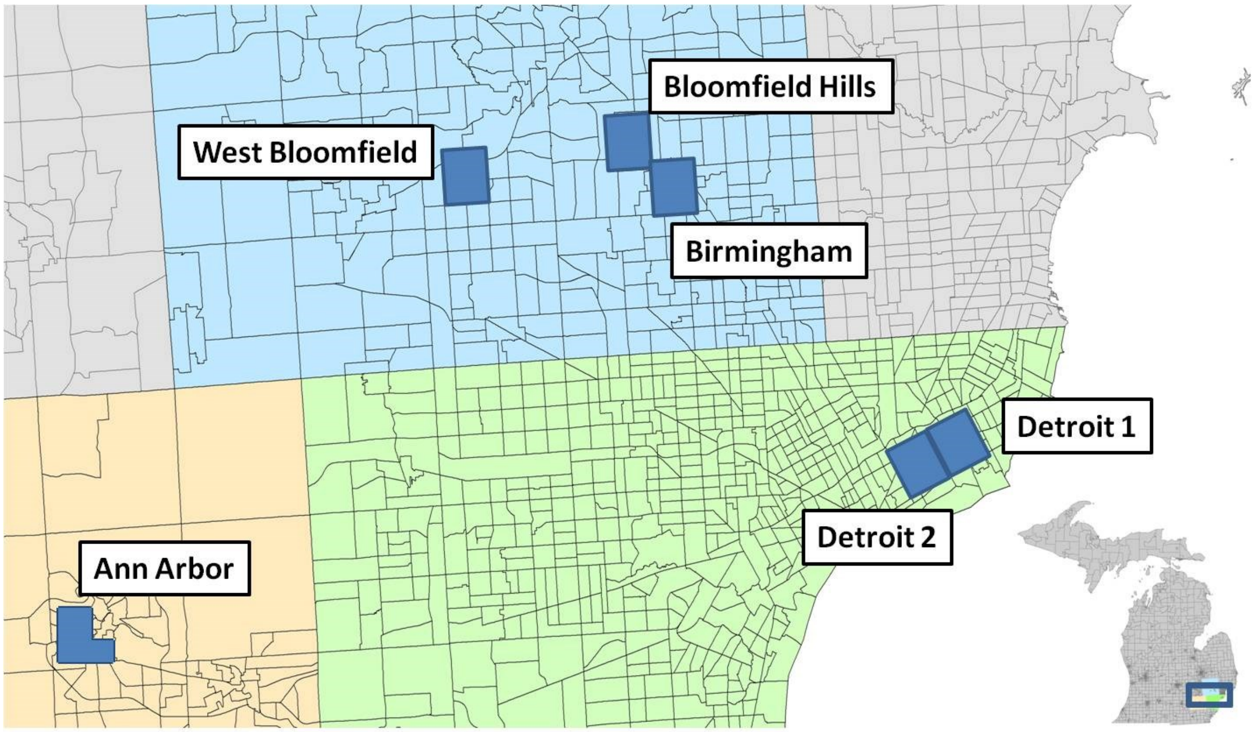
The Predictors would be Socio Economic characteristics (Personal and Household Income, Education, Occupation), and other characteristics affecting the cultural and social attitudes (age, race, number of dependents).

Data

A stratified random mail survey collected data on travel behavior, personal socio-economic and demographic variables, and automobile ownership data. It was decided to send out two surveys per household that was selected into the sample. Introductory prompts were sent out to the sample households in early 2008 introducing the project and alerting the households that they will be receiving these surveys. Thereafter the surveys were mailed out. Two sets of reminder prompts were sent out to the households that had not yet responded to the surveys, two weeks after the surveys were mailed out, and then two weeks thereafter.

In total, there were 1,191 surveys collected. By neighborhood breakdown, there were 128 survey respondents from the Detroit #1 neighborhood, 158 survey respondents from the Detroit #2 neighborhood, 297 respondents from Ann Arbor, 196 respondents from Birmingham, 211 survey respondents from Bloomfield Hills, and 201 respondents from West Bloomfield. The mail survey included detailed questions on travel, such as frequency and purpose of trips, travel mode, and destinations, for a full array of trips, including work, shopping, personal services, and leisure. Respondents were asked to report travel behavior over a typical week while considering seasonal distinctions, for instance, reflecting on differences between winter versus summer travel. The survey response rate was 20%, which is considered good for a mail-out survey administered to the general population, and particularly for a travel behavior survey (Sommer & Sommer, 1997; Zimowski et al., 1997). Figure 32, shown below, is a map with the six study sites.

Figure 32: Study Area



The next step was verifying and completing any incomplete information supplied by the residents on their vehicle ownership and characteristics. This was done by matching the records from each household to a database of vehicle ownership in Michigan, obtained through the Michigan Secretary of State. This dataset contained the make, model, year, and body type for each vehicle registered to each of the addresses in the sample. If any of the information in the surveys was incomplete, it was matched to the vehicle registration dataset. Only missing information in any survey was completed through this verification process. So, if a respondent to a survey said he/she used a 2002 Toyota, and did not provide the model of the vehicle, and if the vehicle registration dataset had a 2002 Toyota Corolla registered to this address, then the survey dataset was updated and the model of "Corolla" was added to the dataset. In essence, if one piece of the puzzle was missing, it was updated. However, if the respondent said they used a different type of vehicle altogether, then the survey response was used (and not the vehicle registration data).

The most number of incomplete entries were from the Detroit neighborhoods. It was also in the two Detroit neighborhoods where many of the vehicles that were actually being used were not registered to respondents' addresses, and therefore not on the Michigan Secretary of State vehicle registration database. Lower income residents in these neighborhoods were extensively using cars that belonged to relatives, or friends, and registered to some other address.

Once the data on vehicles was confirmed and completed, the characteristics of each vehicle mentioned in the survey was matched to a database by the Environmental Protection Agency (EPA) wherein emissions and fuel economy was obtained. This database is the Green Vehicle Guide, maintained by the Office of Transportation and Air Quality, a division of the EPA. This database is essentially the same as that of a 'window sticker' that would get put on a vehicle if it would be up for sale. All this information is specific to the make, model, year, and State that the vehicle is registered in. The information is broken down into three parts: vehicle specifications, environmental information, and other information. Appendix B in the appendices shows an example of the information provided for a 2005 Lexus ES 330, registered in Michigan. Fuel economy information, if not available from the EPA database, was retrieved by performing a similar vehicle specific search on the fueleconomy.gov website, maintained by the US Department of Energy. Appendix C in the appendices shows an example of the information provided for a 2005 Lexus ES 330 vehicle registered in Michigan.

Collecting the physical attributes of the neighborhood sites was the next step in the data collection process. Field trips were made to the study sites to collect information on built environment objective data, such as the land use (residential, commercial, retail, industrial) for each structure in the study neighborhood, residential building type (single family, apartments, townhomes, industrial), and an assessment of abandoned properties (these were those that were visibly abandoned, with boarded up windows and doors). During this period, mid- to late-2008, the problem with decreasing real estate prices, and increasing foreclosures, abandonment and vacancies was extensive. During the course of survey collection, over 900 homes to which the surveys were sent had been vacated. Field trips and returned survey packets and prompts corroborated that over 75% of the vacated and abandoned houses were from the urban Detroit neighborhoods.

The study neighborhoods were drawn up in AutoCAD and ArcGIS. The AutoCAD images helped with the portrayal of the built environment (the urban form), while the ArcGIS maps were used to calculate connectivity and document the land use mix. Connectivity was calculated by counting the number of 4-way intersections within the neighborhood boundaries. Land use mix is calculated as the number of non-residential structures (commercial, retail, institutional and industrial) within the neighborhood boundaries. Lastly, the data on the location and number of bus-stops within each neighborhood was also collected. For the urban Detroit and the Ann Arbor neighborhoods, the coordinate locations for the bus-stops were provided by the Detroit Department of Transportation (DDOT) and the Ann Arbor Transportation Agency (AATA) respectively. For the other three suburban neighborhoods of Birmingham, Bloomfield Hills, and West Bloomfield, the locations were taken from Google maps.

Methodology

This section details the data used in the analyses and the different analyses performed to explore the neighborhood travel behavior. The basic database has demographic, vehicle, and travel behavior data for respondents in the six neighborhoods, which are categorized into three different neighborhood typologies—higher density urban (HDU), higher density suburban (HDS), and lower density suburban (LDS). A list of those variables can be found in the Code Book (see Appendix D).

One set of data for this analysis involves the built environment objective data, collected from neighborhood land use and site surveys. Information on land uses (residential, commercial, retail, and industrial), building types (single family, duplexes, apartments, and factories), and their concentration within the neighborhoods were collected during the site surveys. This data was also coupled with connectivity data, the concentration of 4-way intersections within the neighborhoods, and this built environment objective data all went into defining the three neighborhood typologies (see table 8 and 9).

Rationale for the Neighborhood Typology Grouping

With respect to basic community characteristics that distinguish these neighborhood groupings, a number of distinction are worth noting. The two HDU neighborhoods are adjacent to each other and have the same built environment characteristics. As shown in table 8, the two Detroit neighborhoods have similar densities, connectivity and accessibility characteristics. It is also important to note that a big section of land in the Detroit 2 neighborhood is one that was occupied by the Chrysler Plant. Therefore, density figures, connectivity and accessibility measures are lower compared to the Detroit 1 neighborhood. An important difference between the Detroit urban neighborhoods and the higher density suburban neighborhoods, of course, is that the Detroit neighborhoods are lower income and predominately African American, and these neighborhoods are experiencing severe disinvestment and decline. These two Detroit neighborhoods, while similar to each other, are very different socio-economically, demographically, and racially from any other neighborhood grouping, and were grouped together to form the 'higher density urban' (HDU) group. Table 9 shows the built environment characteristics of the combined neighborhoods.

Table 8: Built Environment characteristics by Neighborhood

	Detroit 1	Detroit 2	Ann Arbor	Birmingham	Bloomfield Hills	West Bloomfield
Land Use Characteristics (numbers per square mile)						
Single Family Detached Homes	1542.1	1024.7	1575.4	1416.3	424	716.3
Non-residential structures	77.7	38.1	57.3	54.8	22.6	1.6
Connectivity (numbers per square mile)						
4-Way Intersections	77.7	49.2	31.1	41.4	5.2	5.2
Population Density (numbers per square mile)						
Density 2010	4162	3644	5427	3828	1141	2686
Density 2008*	4708.8	4040.6	5448.6	3788.4	1134.2	2720.8

*Estimated density based on decade change values

Table 9: Built Environment characteristics by Neighborhood Type

	HDU	HDS	LDS
Land Use Characteristics (numbers per square mile)			
Single Family Detached Homes	1283.4	1495.9	570.2
Non-residential structures	57.9	56.05	12.1
Connectivity (numbers per square mile)			
4-Way Intersections	63.5	36.3	5.2
Population Density (numbers per square mile)			
Density 2010	3903	4627.5	1913.5
Density 2008*	4374.7	4618.5	1927.5

*Estimated density based on decade change values

Moving outward, the Ann Arbor neighborhood and the Birmingham neighborhood have similar built environment characteristics as the HDU neighborhoods, but these are neighborhoods in more dynamic and robust communities. Although they are not adjacent to each other, they are in suburban areas with strong urban cores and they have similar density characteristics as the inner city Detroit neighborhoods. These densities would be considered relatively high in the Michigan context. They also have similar gridiron street patterns and hence similar connectivity characteristics. These neighborhoods are also characterized by mixed land uses, particularly along major roads and the central area of these neighborhoods, their robust and dynamic urban cores. Ann Arbor has more of a mixed use visible because adjoining and to the south of the downtown area is the University of Michigan campus and this adds to the diversity of uses within the neighborhood. Even though the Birmingham neighborhood does not have a university within its boundary, it has built environment characteristics that are similar to Ann Arbor, a higher density urban core with a robust land use mix. Both of these neighborhoods are also generally upper-income and contain a population that is largely white. Given their similar built environment characteristics, which are relatively unique development patterns within Michigan, the Ann Arbor and the Birmingham neighborhoods were combined to represent the 'higher density suburban' (HDS) group.

The Bloomfield Hills and the West Bloomfield neighborhoods are situated in adjacent municipalities and have very similar built environment characteristics. These neighborhoods have low densities, road patterns that are curvilinear and these neighborhoods are almost completely single use zoned. Socio-economically, these areas are generally wealthy and predominantly White. Given their built environment characteristics, these two neighborhoods were combined to represent the ‘low density suburban’ (LDS) group. The resultant study area consists of three neighborhood ‘types’ that have a large enough population base for effective analyses on travel behavior and environmental burdens to be conducted.

Quantitative Analyses

In this intra neighborhood focus, apart from descriptive statistics, three quantitative analyses are conducted. A Discriminant Analysis was conducted first on the entire file that helped distinguish between the three neighborhood types. This analysis aims to predict which group an observation would fall in, given some characteristic variables. In this study, the ‘groups’ refer to the three neighborhood typologies: HDU, HDS, and LDS. Apart from prediction, this analysis also aims to enrich the understanding of the data and the characteristics of the observations in each group. The result is a ‘function’ that is a linear equation which would help in distinguishing in which group an observation would fall.

After the Discriminant Analysis was conducted, the grand file was separated into three separate files, one for each neighborhood typology (HDU, HDS, and LDS). On each of the three files, Cluster Analyses (to see what groupings emerged from the data) and Regression Analyses (to test the hypotheses) were conducted. A Cluster Analysis also helps in grouping the observations into groups that share common characteristics. However, a Cluster Analysis and a Discriminant Analysis are different. The Discriminant Analysis helps distinguish between known groups (in the case of this study, this analysis would help in distinguishing between observations in the HDU, HDS and the LDS neighborhoods). A Cluster Analysis, on the other hand, helps to distinguish between unknown groups. In the case of this study, this analysis is conducted on each neighborhood typology and the observations in each file are not grouped into any category. The Cluster Analysis would help in categorizing the observations into groups that share some similar characteristics.

Lastly, Regression Analyses were conducted to see the effect of socio-economic characteristics on travel behavior and environmental burdens, while holding the built environment constant. This analysis helps in testing the hypotheses laid out earlier. Regressions aim to predict or determine causal effects of independent variables on a dependent variable. Another aim is to also determine associations between independent and dependent variables. In the case of this study, the Regressions are conducted to mainly determine the associations between socio-economic variables of residents in a neighborhood typology and their travel behavior and contributions to environmental burdens. The detailed methodology for each analysis is provided below.

Discriminant Analysis (DA)

The Discriminant Analysis shows what factors are important in the grouping of residents in the three neighborhood types: higher density urban, HDU (both neighborhoods in Detroit), higher density suburban, HDS (these include the neighborhoods in Ann Arbor and Birmingham), and lower density suburban, LDS (these include neighborhoods in Bloomfield Hills and West Bloomfield). Starting with a stepwise DA on the variables shown in table 10, the analysis selected the following variables as significant for the DA: VEHALL, AGE, HINCOME, EDUC, INC_SUPPORTS, Pct_NonWorkTrips_Walk, and Annual_CO_Emissions.

Table 10: Variables used in a Stepwise DA

Demographic Variables	Vehicle Variables	Travel Variables
AGE	VEHYOU	Pct_WorkTrips_Walk
PINCOME	VEHALL	Pct_WorkTrips-Drive
HINCOME	VEHYEAR	Pct_NonWorkTrips_Walk
EDUC	VEHCYLINDER	Pct_NonWorkTrips_Drive
INC_SUPPORTS	VEHMILES	Pct_AllTrips_Transit
NUM_CHILD		Ann_WorkMiles_Walk
		Ann_WorkMiles_Transit
		Ann_WorkMiles_Drive
		Ann_NonWorkMiles_Walk
		Ann_NonWorkMiles_Transit
		Ann_NonWorkMiles_Drive
		Ann_AllMiles_Walk
		Ann_AllMiles_Transit
		Ann_AllMiles_Drive
		Ann_Fuel_Consump
		Ann_CO_Emissions

After checking for and transforming the variables for 'normality', the DA was rerun with only the above selected seven variables, transformed as necessary. Only the 'Age' and the "Inc_Supports" variables did not need any transformation, however, log transformations were done for 'VehAll', 'Educ', 'Pct_NonWorkTrips_Walk' and 'Ann_CO_Emissions', and square root transformation was done for the 'HIncome' variable. Appendix D shows the distributions of the variables used in this analysis (before and after transformations). Many of the variables have skewed distributions, however, only those used in the analysis have been transformed for normality as this is a prerequisite for these analysis. Initially, the analysis included 200 cases from a total of 960 cases. A large number of cases are excluded because at least one variable was missing. Missing data is an issue with this dataset and all analyses will encounter this problem. However, the 200 cases included satisfy a general requirement that there should be a minimum of 5 cases per variable included in the analysis, and since this analysis has 7 variables, the minimum number of cases should be 35.

Another general requirement states that there should preferably be a minimum of 20 cases per variable, with 7 variables in the study, the preferred number of cases would be 140, and this analysis satisfies that requirement as well. However, it should be cautioned that when these 200 cases get divided into the 3 groups (of neighborhood types), Group 1 (Higher Density Urban) has 15 cases which satisfies a requirement that the group membership should be greater than the number of variables, but it does not satisfy the requirement that it would be preferable that the membership be a minimum of 20 cases. In this case, the results can still be interpreted as long as the above caution is expressed. The Wilks' Lambda test shows that both Functions are significant in the classification of groups in this analysis.

The Box's M statistic tests the null hypothesis that *the dispersion matrices across the subgroups of the dependent variable are homogenous*. With a significance of .027, this result would reject the null hypothesis at a 99% threshold and accept it at a 95% threshold. If the null hypothesis is rejected, it means that the variance among the three groups is not homogenous, and we should use the variance between the groups. In that case, we would run the DA using the between-group covariance matrix for classification. If we do not reject the null hypothesis, it means variance between the groups is homogenous and we should look at the variance within each group. In that case, we use the pooled or within-group covariance matrix for classification. The within-group covariance matrix was utilized for classification because the between-group classification did not improve the results. Lastly, the Mahalanobis Distance statistics were used to calculate and ensure that the cross validated probability of 72.5% classification was significantly higher than a classification achieved purely 'by chance'.

Cluster Analysis (CA)

In the following analyses, the focus shifts from what separates the three neighborhood types, to what separates the residents within each neighborhood type, while controlling for the built environment. Factor and Cluster Analyses have been conducted in this line of research so as to quantitatively identify different groups of information (Shay and Khattak, 2012). This analysis is done twice per file, separately for all three files; higher density urban (HDU), higher density suburban (HDS), and lower density suburban (LDS). The first Cluster Analysis is done using only the demographic variables to see the clusters that emerge. The second Cluster Analysis is done using all variables in the file to see the effect of travel behavior and emissions on the clusters.

To get to the Cluster Analysis, the following steps were performed. A Principal Components Analysis (PCA) was performed on the variables in the files. The components generated are orthogonal and multicolinearity issues are contained in this step. The component scores were then used in a Hierarchical Clustering technique that would lead to the decision on how many clusters were desirable and appropriate. Those numbers of clusters were then used in a K-means clustering analysis for the final result. Lastly, a table is presented that gives some insight into the averages of the main variables in each component so that those 'Clusters' may be understood. Results are summarized in table 11 below:

Table 11: Summary of PCA and Cluster Analyses

	Higher Density Urban	Higher Density Suburban	Low Density Suburban
CA – Demographic & Socio-Economic Variables			
PCA Components	Socio-economic charac. Dependants Race Employment # Vehicles Owned Engine Size	Employment Income Dependants Vehicle Age/Usage # Vehicles owned Race	Dependants Employment Vehicle Age/Usage Race # Vehicles owned Admin_Service Occup.
# of Clusters	4 (1,29,21,1)	4 (118,83,5,20)	8 (43,20,37,22,60,3,7,1)
<4 cases	2	0	2
See Table #	6	8	10
CA – All Variables			

PCA Components	Mode = Transit
	Mode = Walking
	Destination Work
	Energy Usage
	Socio-economic charac.
	Vehicle Age/Usage
	Race
	Dependants
	# Vehicles owned
		Non-Work Trips
		Energy Usage
		Mode = Transit
		Work Trips
		Socio-economic charac.
		# Vehicles owned
		NonWork trips by Transit
		Dependants
		Vehicle Age/Usage
		Race
		Employment (for wages)
		Gender & Laborer Occup
			*
			Energy Usage
			Work Trips
			Non-Work Trips
			Employment
			Dependants
			Vehicle Age/Usage
			Race
			# Vehicles owned
			Mode = Walking
			Laborer
			Admin_Service Occup

# of Clusters	4 (1,1,19,10)	8 (52,3,19,64,3,4,3,6)	6 (18,12,2,59,24,7)
<4 cases	2	3	1
See Table #	7	9	11

* Took out Transit mode as there are no travels by this mode in this neighborhood type

Regression Analyses

To test the hypotheses laid out earlier, this last set of analyses is run separately on the three neighborhood type files (similar to the Cluster Analyses). The purpose of this analysis is to capture the relationship of the various characteristics of the residents in a particular neighborhood type to their travel patterns (trip mode and annual miles) and subsequent energy use. The results are intended to be relational rather than causal as has been stressed in other studies on the topic (Cervero and Kockelman, 1997). Conducting this analysis separately on the three neighborhood types allows for the built environment to be controlled and for a focus to be placed on the 'other' factors that impact travel behavior and environmental burdens.

The following steps were performed in this analysis. Starting with the higher density urban typology, neighborhoods that had the least and the 'messiest' data, dimensions from the Principle Component Analysis were examined on the demographic variables done for the earlier Cluster analyses. From each dimension, a variable that had one of the highest loadings was used as my independent variable, thus controlling for multicolinearity issues. The Independent variables were *Num_Children, Dum_Black, Dum_White, Educ, Dum_Employed, HIncome, and Age*. The dependent variables were *the percent of trips by each mode (Walking, Transit, Driving), the annual miles traveled by each mode, for each purpose (Work, Non Work, and All Trips), and the vehicle characteristics and environmental burdens (specifically gasoline consumption and carbon monoxide emissions)*. This analysis was then conducted on the other two neighborhood typologies, the higher density suburban and lower density suburban neighborhoods. In all the analyses, data variables were transformed to get them as close to a normal distribution as possible. As followed for the Discriminant Analysis, the rule that the skewness and kurtosis should fall within -1.0 and +1.0 was followed. Appendix F shows the variables before and after transformations as used in the regression analyses.

Even after transformations, there were variables that did not fit the skewness-kurtosis rule mentioned above. An issue with empirical data is that even though some observations seem like outliers, they in fact are not and represent the large range of behaviors present in the population.

This is largely the case with the dependent variables (specially the percentage traveled by different modes) in this study. However, other assumptions for OLS regressions were observed and since the main aim is to get at environmental burdens, the regression models were suitable for the datasets.

Caution

Caution is raised here as the race variables were coded as dummy variables (Dum_White coded as 1 for white and 0 for all other races and Dum_Black coded as 1 for Black and 0 for all other races). The Higher Density Urban file did not have enough white respondents, just as the Low Density Suburban file did not have enough black respondents. The Higher Density Suburban file had an adequate number of white and black respondents to run the analysis. Consequently, the regression models have both these dummy variables included and the 'other' race would be the reference. Although the data collected is not ideal for an analysis on 'race' as mentioned above, this variable has been included in order to find out if there was any significant relationships that emerged from the analyses. Also, some of the neighborhoods did have considerable variability in ethnic and racial composition, and so to keep it consistent, this variable was kept in the analyses. Results should be viewed with caution.

Another issue is raised specially for the Low Density Suburban neighborhoods. Respondents living in these neighborhoods undertook almost no travel by Transit, and therefore the regression results for Transit trips should be read with caution.

Commentary

This chapter has presented the main research question for this study, a set of hypotheses formulated, and the data and methodology that was used to get at the results of the study. The quantitative methods discussed above are critical to the study as these have been chosen so that the main research question and the related hypotheses are sufficiently answered.

Apart from quantitative analyses, a separate line of simple, qualitative analyses is also conducted so as to uncover more detail and rich information that is critical to this study. This simple data presentation helps uncover layers of valuable information that put this study and its results into a niche that has not been explored by existing studies. Although this chapter does not present qualitative assessment of the data, it is included in the next chapter that discusses the results of all these analyses in detail.

Chapter VI - Results and Discussion

Analysis of Variance

Before the results of the first analysis (the Discriminant Analysis) are presented, the table below (Table 12) shows the mean values of the different continuous variables used in the various analyses. Using ANOVA, the significance of the differences of the averages across the three neighborhood types is presented. The table will show whether the mean of each variable in each neighborhood type is significantly different from the mean of that variable in the other neighborhood types.

Vehicle Characteristics

Table 12 shows that most of the variables used in this analysis have averages for the HDU neighborhoods that significantly differ from those of the suburban neighborhoods. Access to vehicles increases as you move from the urban neighborhoods to the high density suburban neighborhoods to the low density suburban neighborhoods. While the residents in the urban neighborhoods have access to less than one vehicle themselves and just about one vehicle per household, the suburban neighborhood residents have access to more than one vehicle on average for themselves and two plus vehicles per household. The average year of the vehicle in use in the HDU Neighborhoods is about 1999. This means that the average car was about ten years old in the Detroit neighborhoods. The year of the vehicle is the only variable in this section that is not significantly different in the three neighborhoods, although it is evident that the suburban neighborhoods have newer cars.

Table 12: Analysis of Variance Table across the three Neighborhood Types

Variable	Description	Higher Density Urban (1)		Higher Density Suburban (2)		Low Density Suburban (3)	
		N	*Mean*	*N*	*Mean*	*N*	*Mean*
VehYou	# of vehicles available to you	208	0.81 (2,3)	376	1.24 (1)	318	1.35 (1)
VehAll	# of vehicles available to all in household	160	1.00 (2,3)	334	1.95 (1,3)	276	2.22 (1,2)
VehYear	Year of the vehicle	159	1998.72	384	2001.98	323	2003.91
VehCyl	Number of cylinders	149	5.80 (2)	369	5.23 (1,3)	303	5.81 (2)
VehMiles	Miles on the vehicle	121	78929.30 (2,3)	377	62672.20 (1,3)	319	42590.57 (1,2)
Age	Age of respondent	227	52.10 (3)	391	50.99 (3)	317	57.04 (1,2)
Educ	Years of Education received	225	12.95 (2,3)	389	17.08 (1)	324	16.75 (1)
Num_Child	# of children (under 18yrs) living at home	208	0.87 (2)	377	0.54 (1)	314	0.65
Inc_Supports	# of people your income supports	212	2.22 (3)	377	2.44 (3)	309	2.73 (1,2)
PIncome	Personal Income	209	23995.22 (2,3)	356	62359.55 (1,3)	278	73417.27 (1,2)
HIncome	Household Income	201	30422.89 (2,3)	347	96123.92 (1,3)	273	108516.48 (1,2)
Pct_WorkTrips_W	% of Work Trips by Walking	93	13.50 (3)	265	16.03 (3)	196	5.53 (1,2)
Pct_WorkTrips_T	% of Work Trips by Public Transit	93	13.46 (2,3)	265	6.66 (1,3)	196	0.09 (1,2)
Pct_WorkTrips_D	% of Work Trips by Driving	93	73.04 (3)	265	77.30 (3)	196	94.38 (1,2)
Pct_NonWorkTrips_W	% of Non-Work Trips by Walking	220	23.63 (3)	389	21.47 (3)	323	6.83 (1,2)
Pct_NonWorkTrips_T	% of Non-Work Trips by Public Transit	220	8.31 (2,3)	389	1.13 (1)	323	0.18 (1)
Pct_NonWorkTrips_D	% of Non-Work Trips by Driving	220	68.06 (2,3)	389	77.39 (1,3)	323	92.99 (1,2)

Table 12 (cont'd)

Variable	Description	Higher Density Urban (1)		Higher Density Suburban (2)		Low Density Suburban (3)	
		N	*Mean*	*N*	*Mean*	*N*	*Mean*
Pct_AllTrips_W	% of All Trips by Walking	223	22.97$^{(3)}$	392	20.12$^{(3)}$	325	6.92$^{(1,2)}$
Pct_AllTrips_T	% of All Trips by Public Transit	223	9.84$^{(2,3)}$	392	2.83$^{(1,3)}$	325	0.20$^{(1,2)}$
Pct_AllTrips_D	% of All Trips by Driving	223	67.19$^{(2,3)}$	392	77.05$^{(1,3)}$	325	92.88$^{(1,2)}$
Ann_WorkMiles_W	Annual miles to Work by Walking	93	287.15	265	130.68	196	88.59
Ann_WorkMiles_T	Annual miles to Work by Transit	93	299.31$^{(2,3)}$	265	64.18$^{(1)}$	196	2.92$^{(1)}$
Ann_WorkMiles_D	Annual miles to Work by Driving	93	1849.67$^{(3)}$	265	1926.99$^{(3)}$	196	3354.82$^{(1,2)}$
Ann_NonWorkMiles_W	Annual Non-Work miles by Walking	220	224.40$^{(2,3)}$	391	99.89$^{(1)}$	324	68.11$^{(1)}$
Ann_NonWorkMiles_T	Annual Non-Work miles by Transit	220	259.65$^{(2,3)}$	391	9.13$^{(1)}$	324	2.28$^{(1)}$
Ann_NonWorkMiles_D	Annual Non-Work miles by Driving	220	1214.64$^{(3)}$	391	855.59$^{(3)}$	324	1921.06$^{(1,2)}$
Ann_AllMiles_W	Total annual miles for trips by Walking	223	341.14$^{(3)}$	392	187.98	325	121.32$^{(1)}$
Ann_AllMiles_T	Total annual miles for trips by Transit	223	380.98$^{(2,3)}$	392	52.49$^{(1)}$	325	4.03$^{(1)}$
Ann_AllMiles_D	Total annual miles for trips by Driving	223	1969.69$^{(3)}$	392	2156.09$^{(3)}$	325	3938.36$^{(1,2)}$
Ann_Fuel_Consump	Annual Fuel Consumption (in gallons)	145	99.64$^{(3)}$	355	106.31$^{(3)}$	286	212.92$^{(1,2)}$
Ann_CO_Emissions	Annual Carbon Monoxide Emissions (gms)	146	8674.03$^{(3)}$	356	8870.33$^{(3)}$	287	16300.46$^{(1,2)}$

*The numbers in superscript parentheses show which group that mean is significantly different from. For example, the HDU mean for VehYou is given as 0.81$^{(2,3)}$. This means that this average is significantly different from that of Group 2 (HDS) and Group 3 (LDS). All significance is at the 0.05 level.

One possibility that should be considered in this discussion is that some suburban residents have older cars that they maintain as ‘classics’ and that this factor might be responsible for increasing the average age of the vehicles in these neighborhoods. An average of about 95,000 miles on the vehicles owned and operated by the HDU residents suggests that they have been around for some time and used considerably. The miles drop drastically as we move to the suburban neighborhoods, with the HDS vehicles averaging 63,000 miles and the LDS vehicles averaging 43,000 miles. This can imply that residents in LDS neighborhoods have more vehicle choice for their different trips and also that their newer vehicles have lower miles on them. The cylinders on the vehicles tell yet another story though. The HDU and the LDS neighborhood vehicles have more cylinders from those on the vehicles of the HDS neighborhoods. A couple things that might help understand this distinction: 1) the HDU residents have older, American vehicles that typically have larger engines, and 2) the LDS residents have newer, however, more powerful vehicles that have more cylinders. Many of the respondents from the LDS neighborhoods live in areas that have unpaved roads or terrain leading to their homes and require more powerful, all-wheel drive vehicles, particularly during winter months. The HDS residents have smaller vehicles with fewer cylinders. Even though they have newer vehicles, they probably do not need the power associated with larger engines and they may be more environmentally conscious, which in part leads to them living in higher density neighborhoods.

Demographic Characteristics

With respect to demographic variables, we see that the residents of the urban (HDU) and higher density suburban (HDS) neighborhoods are similar in age (about 52 and 51 years old respectively), while the low density suburban (LDS) residents were comparatively older (about 57 years old). The LDS respondents tended to maintain higher incomes. The move to the lower density suburbs as you advance in your career and move up the socio-economic ladder can explain the older average age of the West Bloomfield and Bloomfield Hills neighborhood respondents. The respondents tended to be slightly wealthier and older in the lower density suburbs. The lowest mean age among the HDS respondents was likely affected by University of Michigan in Ann Arbor and the student respondents who live in this neighborhood.

With regard to educational attainment, there are notable differences in averages across the neighborhoods. The urban respondents have lower education levels (graduated high school), while the HDS and LDS neighborhoods have higher levels (a Bachelor's degree). This also translates into differences in the average income levels by the neighborhood groupings. The urban respondents have lower levels of average Personal ($24,000) and Household Income ($30,500) compared to the suburban respondents. Even among the suburban respondents, those in the HDS neighborhoods have a lower Personal ($62,000) and Household income ($96,000) when compared to respondents living in the LDS neighborhoods (Personal Income at $73,000 and Household Income at $108,000). Overall, there is a stark difference in the earnings of the Urban and the Suburban residents.

With regard to dependents, the numbers of children under the age of 18 years living at home is the greatest in the urban neighborhoods. The suburban neighborhoods, however, have a higher number of people in the household that the respondents' incomes support. This might have something to do with older children living at home or having older parents being supported by these families. Having older parents living in the house in the lower density suburbs might have also contributed to the older average age in these neighborhoods.

Travel Behavior

When we think of work based trips, it is understandable that we will have a limited distance that people can, and are willing, to walk to get to work. The destination has to be close enough to encourage people to walk to their workplace, rather than take an alternate mode of travel. The HDU and the HDS residents undertake about 15% of their work trips by walking. The LDS residents conduct about 6% of their work trips by walking. This difference is due to the fact that the LDS neighborhoods are single use, disconnected, and less dense neighborhoods where very few people will have a work destination that is close enough to walk to. This distance factor is reflected in the annual miles to work by walking. The HDU residents travel about 284 miles to work by walking annually, while the LDS residents travel just about 88 miles annually. Driving as a mode of travel, on the other hand, accounts for between 75% (HDU) to 95% (LDS) of work trips. The HDU and HDS neighborhood residents drive shorter distances annually to work, while the LDS residents drive twice the amount, indicating that their work places are further from their residence neighborhoods.

While transit is an option for the HDU and the HDS neighborhood respondents, it is not a practical option for the lower density suburban neighborhood respondents, and hence there is limited travel by transit in the lower density outer suburbs. This mode of travel is used, however, by respondents in the HDU and HDS neighborhoods. The HDU residents use transit for almost the same percentage of work trips as walking and travel almost the same annual distance to work by transit as they do by walking. The HDS neighborhood residents, on the other hand, walk more for their work trips than use transit and similarly, they travel longer distances annually by walking than they do by transit for work based trips.

Since work trips are considered ‘essential’ trips, there is less of an option to use non-automobile modes of travel for such a structured travel need. The non-work trips, on the other hand, show that people do exercise the option of using transit and walking to their destinations when they are not bound by time and location constraints. The percentage of trips by walking for non-work trips is higher in both the HDU and HDS neighborhoods. The use of transit actually decreases with non-work based trips, indicating that the residents choose walking over the use of transit for these trips. It also means that non-work trips are also likely closer to the respondents’ homes, close enough for walking.

For the LDS neighborhoods, there is not much of a difference between the walking and the transit options, likely because of the much greater distances to daily destinations from these neighborhoods. Residents of the LDS neighborhoods have a relatively homogenous travel mode and use their vehicles for over 90% of all their trips, compared to the urban residents who use their vehicles for about two-thirds of all their trips. As far as annual distances are concerned, the residents in the LDS neighborhoods travel double the total distances annually for all trips by car, compared to residents in the HDU neighborhoods. Consequently the LDS neighborhoods, when compared to the HDU and HDS neighborhoods, consume more than double the fuel annually and are responsible for emitting more than double the pollutants.

One thing to bear in mind is that the trip purposes are divided into work and non-work trips. However, many respondents did not enter in details for both trip purposes, which meant that there were many missing values. When looking at the annual work miles and non-work miles, the means reflect the presence of the missing values within each trip purpose. Consequently, the average annual miles (by various modes) to work and non-work destinations might not add up to the average annual miles for all trips combined. For example, if a respondent said he traveled 10 miles to work by driving but did not say anything about the travel to non-work trips, he would be counted in the average for work trips and all trips combined, but he would not be counted in the non-work trips. Such instances, give rise to different Ns and the averages (mean values) would be reflective of that and therefore, the average values for work trips and non-work trips might not add up to the average value for all trips combined (for any particular mode).

After looking at the averages for the different variables and whether they differ significantly across the neighborhood types, the next analysis conducted is the Discriminant Analysis. Although this analysis also aims at distinguishing between the three neighborhood types, its importance lies in formally indicating what precise variables contribute to the distinction. We know that the three neighborhoods are different, however, this analysis explores the specific variables that distinguishes the three neighborhood typologies.

Discriminant Analysis (DA)

Overall, the Discriminant Analysis was telling and informative in revealing what distinguished the residents living in the three neighborhood types. Variables that were included in this analysis were not only demographic, but also those related to vehicles and travel patterns (see Table 13). The table below shows the description of the variables selected for this analysis.

Table 13: Variables used in the Discriminant Analysis

Variables	Description
Ln_VehAll	Number of vehicles accessible to all in the household – Log normal transformed
Age	Age of the respondent
Sqrt_HIncome	Annual Household Income – Square root transformation
Ln_Educ	Number of years of education received - Log normal transformed
Inc_Supports	Number of household members that the respondent's personal income supports
Ln_Pct_NonWorkTrips_Walk	Percent of trips to Non-Work destinations that are undertaken by walking - Log normal transformed
Ln_Annual_CO_Emissions	Annual Carbon Monoxide Emissions (in grams) - Log normal transformed

The DA analysis resulted in 2 functions (for 3 groups) as shown in table 14 below:

Table 14: Functions at Group Centroids

	Function	
Neighborhood_Type	1	2
HDU	-2.969	-.220
HDS	.315	-.245
LDS	.024	.791

From the above table we see that Function 1 distinguishes the HDU neighborhoods from the suburban ones and Function 2 distinguishes the two suburban neighborhoods (the LDS neighborhoods from the HDS neighborhoods). The HDU neighborhoods are ignored because they are already distinguished from the other neighborhood types by Function 1. Table 15 below shows the Structure Matrix that identifies the variables that are significantly associated with each Function. In general, values greater than 0.3 are considered to be significantly associated with the function.

Table 15: Structure Matrix

Variables	Function 1	Function 2
Ln_Educ	.830	.170
Sqrt_HIncome	.464	.349
Age	.111	.610
Ln_NonWorkTrips_Walk	.104	-.542
LnAnn_CO_Emissions	-.193	.443
Inc_Supports	-.090	.313
LnVehAll	.182	.309

From the above structure matrix, looking at the values for Function 1, we see Education and Household Income as having the highest contributions to this function that distinguishes the HDU neighborhoods from the suburban ones. In the column for Function 2, Age, Percent of Non-Work trips undertaken by Walking, and Annual carbon monoxide emissions have the largest contributions to this function that effectively distinguishes the two suburban neighborhoods (the HDS and the LDS neighborhoods). As such, the Functions are shown by the following equations:

Function 1 = .240 (LnVehAll) + .055 (LnPct_NonWorkTrips_Walk) - .286 (LnAnn_CO_Emissions) - .166 (Age) - .348 (Inc_Supports) + .817 (Ln_Educ) + .441 (Sqrt_HIncome)

Function 2 = .214 (LnVehAll) - .363 (LnPct_NonWorkTrips_Walk) + .295 (LnAnn_CO_Emissions) + .795 (Age) + .483 (Inc_Supports) + .085 (Ln_Educ) - .127 (Sqrt_HIncome)

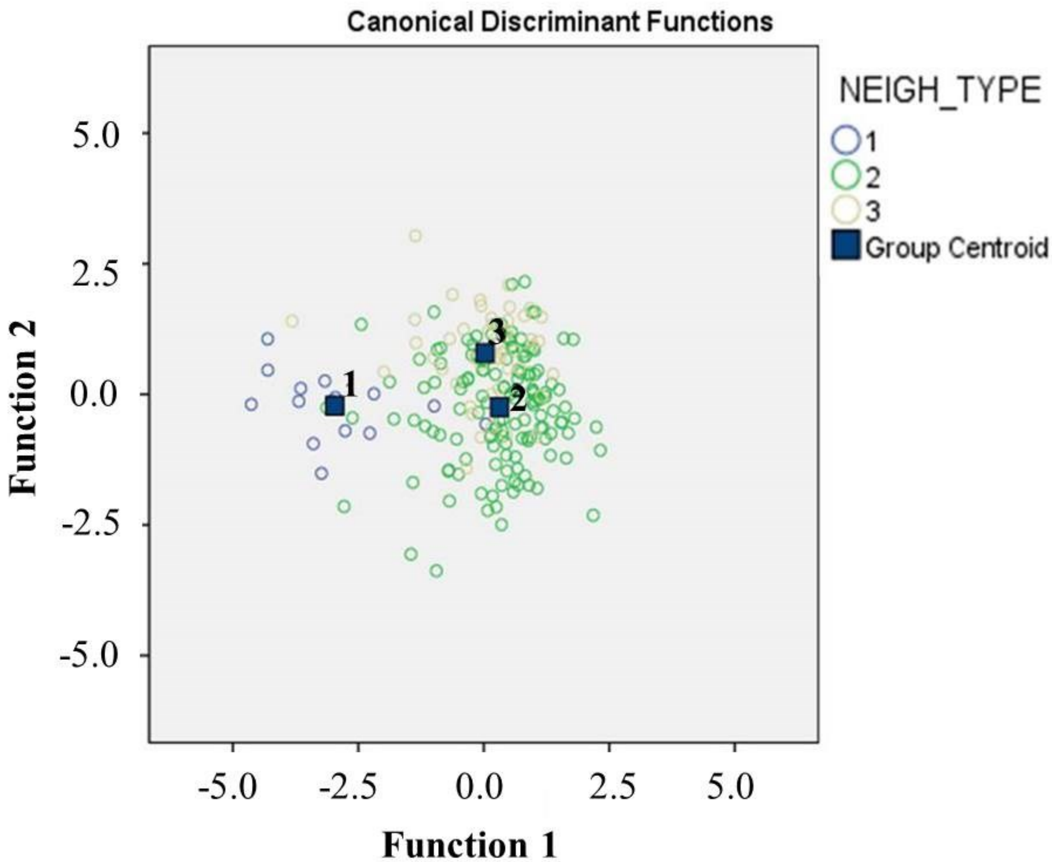
Table 16 below shows the averages of the variables within each group and as a total.

Table 16: Group Statistics

Group	Variables	Mean	Valid N
HDU	LnVehAll	.3697	15
	Ln_NonWorkTrips_Walk	3.0953	15
	LnAnn_CO_Emissions	9.3132	15
	Age	40.9333	15
	Inc_Supports	3.2000	15
	Ln_Educ	2.5092	15
	Sqrt_HIncome	189.0464	15
HDS	LnVehAll	.6158	138
	Ln_NonWorkTrips_Walk	3.3870	138
	LnAnn_CO_Emissions	8.4939	138
	Age	45.5725	138
	Inc_Supports	2.7862	138
	Ln_Educ	2.8600	138
	Sqrt_HIncome	309.0749	138
LDS	LnVehAll	.7277	47
	Ln_NonWorkTrips_Walk	2.9029	47
	LnAnn_CO_Emissions	9.1495	47
	Age	53.5851	47
	Inc_Supports	3.2660	47
	Ln_Educ	2.8515	47
	Sqrt_HIncome	327.0032	47
Total	LnVehAll	.6237	200
	Ln_NonWorkTrips_Walk	3.2513	200
	LnAnn_CO_Emissions	8.7094	200
	Age	47.1075	200
	Inc_Supports	2.9300	200
	Ln_Educ	2.8317	200
	Sqrt_HIncome	304.2859	200

A look at the averages of the variables significant in the first function, distinguishing urban and suburban neighborhoods, shows that the HDU residents have lower levels of education and lower household incomes than residents in the suburban neighborhoods. Averages of the variables significant in the second function, distinguishing suburban neighborhoods, reveal that the LDS neighborhoods had residents that were older, traveled fewer times via walking for non-work trips and were responsible for higher annual carbon monoxide emissions than the residents of the HDS neighborhoods. The canonical functions plot is shown below.

Figure 33: Canonical Functions Plot



Discussion

As mentioned earlier, the HDU and the HDS neighborhoods are more like each other in terms of the built environment than in terms of the socio-economic characteristics of its residents. This comes out in the results of the Discriminant Analysis. Education and Household

Income play a major role in distinguishing the residents of these two neighborhood types. The LDS and the HDS neighborhoods are more alike in terms of residents' socio-economic characteristics, but their built environments are very different. The Discriminant Analysis brings this aspect of the neighborhood typologies out as well. Travel patterns and emissions make up the majority of the variables associated with this function. This is understandable since the LDS neighborhoods are less dense, have less connectivity, and are dominated by single land uses, when compared to the HDS neighborhoods, limiting the use of non-motorized travel options and encouraging travel via private vehicles. This analysis, therefore, effectively shows what was expected: the class dimension that separates the urban neighborhoods from the suburban neighborhoods and the built environment dimension that separates the two suburban neighborhoods that have a resident base with similar socio-economic characteristics.

The next section of this chapter presents analyses by neighborhood type, exploring how variations in socio-economic and demographic characteristics by neighborhood physical form affect travel, gasoline consumption, and associated emissions. This is done for two reasons: first, the analyses center on <u>within</u> neighborhood type differences and secondly, this structure will help present the <u>differences in socio-economic characteristics</u>, travel behavior and environmental burdens while controlling for the built environment.

Higher Density Urban – City of Detroit Neighborhoods

This neighborhood typology typically has lower income, predominantly African-American residents. It is a neighborhood typology—neighborhoods experiencing disinvestment and decline—that is seldom analyzed in travel behavior research. More often than not, these residents live here because it is where they grew up and call this City home. Low house prices were the dominant reason why respondents in this neighborhood typology chose to stay here. However, another important reason was the fact that these homes were their family homes and they were inherited. These residents are typical of lower eastside Detroit residents. The table below has some descriptions of the categorical variables used in the analyses:

Table 17: Breakdown of Categorical Variables

Variable	**Higher Density Urban**	
	Number	*Percent*
RACE		
White	18	8.3
Non White	199	91.7
Black	196	90.3
Non-Black	21	9.7
Total	217	100
OCCUPATION		
Employed (for wages)	83	37.2
Non-Employed	140	62.8
Total	223	100

The above table shows that there were only 18 respondents from these neighborhoods that were White, making up a mere 8.3% of the total respondents. The majority of the respondents were African American, who made up over 90% of the survey respondents. Another striking feature is the 'Employment'. The dummy variable for employment was used to identify everyone that was employed for wages, i.e. a stay at home parent, a student, the unemployed, and the retired were not counted in this category. From table 17, we see that only 37% of the respondents were ‘employed’ for wages. The average age of the respondents in the urban neighborhoods was about 52 years. This also suggests that this group of mainly African American residents did not typically move out of the inner city as they progressed, which is typical of the urban evolution theory. You would expect to find younger residents in the urban neighborhoods, and as you move outward into the suburbs, you would expect to find older residents. This is not the case with the urban typology neighborhoods. We see here a middle aged, mostly unemployed African American resident base. The table below presents the summary statistics for the variables in this neighborhood type. All of the variables included in this table are from the database that contains all the respondents who indicate travel patterns (whether they have a car or not). In the regression analyses, the last two variables in this table (Annual fuel consumption and Annual CO Emissions) are used from the database that has only those respondents that indicated travel patterns by car and had access to a car for their travel. Therefore the averages in the below table will be smaller than those in the regression and other tertiary breakdown tables.

Table 18: HDU - Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Std. Dev.
VehYou	208	0	5	.81	.79
VehAll	160	0	4	1.0	.97
VehYear	159	1965	2009	1998.72	6.5
VehCyl	149	2	8	5.80	1.37
VehMiles	121	30	309872	78929.30	59435.63
Age	227	18	94	52.10	16.26
Educ	225	10	19	12.95	2.52
Num_Child	208	0	8	0.87	1.38
Inc_Supports	212	0	8	2.22	1.53
PIncome	209	5000	115000	23995.22	21715.93
HIncome	201	5000	135000	30422.89	27891.67
Pct_WorkTrips_W	93	0.00	100.00	13.50	26.87
Pct_WorkTrips_T	93	0.00	100.00	13.46	28.00
Pct_WorkTrips_D	93	0.00	100.00	73.04	39.48
Pct_OptTrips_W	220	0.00	100.00	23.63	34.03
Pct_OptTrips_T	220	0.00	100.00	8.31	19.78
Pct_OptTrips_D	220	0.00	100.00	68.06	39.36
Pct_AllTrips_W	223	0.00	100.00	22.97	32.87
Pct_AllTrips_T	223	0.00	100.00	9.84	21.43
Pct_AllTrips_D	223	0.00	100.00	67.19	39.33
Ann_WorkMiles_W	93	0.00	10244.00	287.15	1241.47
Ann_WorkMiles_T	93	0.00	10244.00	299.31	1310.86
Ann_WorkMiles_D	93	0.00	25953.20	1849.67	3430.76
Ann_OptMiles_W	220	0.00	13010.40	224.40	977.50
Ann_OptMiles_T	220	0.00	12766.00	259.65	1047.38
Ann_OptMiles_D	220	0.00	11317.80	1214.64	1706.25
Ann_AllMiles_W	223	0.00	15844.40	341.14	1452.12
Ann_AllMiles_T	223	0.00	15917.20	380.98	1625.60
Ann_AllMiles_D	223	0.00	26410.80	1969.69	3209.19
Ann_Fuel_Consump*	145	0.00	1049.53	99.64	163.03
Ann_CO_Emissions*	146	0.00	72825.48	8674.03	13056.73

* Ann_Fuel_Consump and Ann_CO_Emissions show annual total environmental burdens for travel to end-point destinations.

Cluster Analyses: The Higher Density Urban Neighborhood Typology

A Cluster Analysis is conducted first to see what kinds of groups emerged *within* each neighborhood typology. As mentioned earlier, two sets of Cluster Analyses were conducted for each neighborhood type, one with only the demographic variables and one analysis that included the vehicular and travel behavior variables. For the analysis done with demographic variables on urban neighborhoods, the results showed that the clusters formed differed mainly on: 1) the number of children under the age of 18 living at home; 2) the age of the residents; and 3) whether they were employed (for wages).

Table 19 below shows the results of these analyses. The K-Means 4 cluster analysis shows 2 out of the 4 clusters as having one member each. Although the analyses identify these as 'outliers', it is reflective of the objective data. In reality, these clusters are realistic and can hold their value as individual clusters. A look at these 'outliers' shows some peculiar characteristics of the residents in these neighborhoods. The results are presented below.

First the clusters with low membership numbers (<4) are discussed, clusters 1 and 4, followed by the discussion of the clusters with sufficient membership numbers (>=4), clusters 2 and 3.

- Cluster 1 identified a young (22 years) white respondent, with a higher than average household income, employed within the Administrative and Service Occupations, and having access to a high number of vehicles in the household (4). Looking at the averages presented the table in the beginning of this section, we can see that this resident stands out from the rest.

- <u>Cluster 4</u> identified a similar aged (21 years) young African American respondent, employed in the same industry (Administrative and Service), has access to one vehicle, however, the household income is very low, at $15,000. Both the above groups single out residents that are unique in some way.
- <u>Cluster 2</u> presented respondents that are younger than the average aged (41 years), almost all African American, with a household income that is higher than the average for those neighborhoods ($47,000). Most of these are employed for wages, have a child under the age of 18 living at home and have access to a car.
- <u>Cluster 3</u> brought together a group of mainly African American residents who were older than the average aged resident (58 years) and consequently had barely any children under the age of 18 living at home. These respondents had a higher than average household income (for the neighborhood), even though less than half of them were employed for wages.

The analysis done with all variables on this neighborhood type reveal differences mainly in: 1) the annual miles for work related trips done by walking; 2) annual fuel consumption; 3) carbon monoxide emissions; 4) income; 5) education; and 6) miles on vehicles. In essence, socio-economic characteristics as well as some travel related characteristics were brought out (*see Table 20*). Clusters 1 and 2 came out as having low membership (less than 4 each). Again, these are anomalies in a way, but they may also stand as individual groups with these particular characteristics. The results are listed below:

- Cluster 1 identified a resident that is African American, has a lower than average household income, even after being employed as a Professional. This resident is unique because of his travel behavior. More than 20% of his trips to non-work and all destinations are by transit and walking. Consequently, he has access to a vehicle that has very low miles on it (28,000), even after using it for one third of the trips to work.
- Cluster 2 identified a resident that has a very low personal income, being employed for wages, and conducting about a third of the work trips by driving. He has almost no other trips by walking or transit and that is probably why this person has an unusually high number of miles on his vehicle.
- Cluster 3 identified a group of almost all African American residents employed for wages, with an about average personal income (for the neighborhood). They do not undertake any trips by transit, only a very few trips by walking, which leaves the bulk of their trips as being done by driving. Understandably, their vehicles have high mileage on them and they are responsible for a greater amount of environmental burdens (i.e. they consume more fuel and emit more Carbon Monoxide).
- Cluster 4 is similar to Cluster 3 in travel patterns, but different in socio-economic characteristics. They are mostly employed as professionals, have higher personal incomes, yet have fewer miles on their vehicles, even after depicting a similar travel pattern as the previous cluster. That is, they maintain high fuel consumption and emit high pollutant levels.

Table 19: Clusters Analysis on Demographic and Socio-Economic Variables – HDU

CL	SES			Dependants		Race		Empl		Veh_Ownership		Cylinder
	HIncome	Educ	Prof	#Child	Age	Wh	Bl	Empl	Admin	Veh-you	Veh_all	
1	45000	14	1	1	22	1	0	1	1	4	4	6
2	46034	14.2	0.31	1.07	40.7	0.03	0.97	0.83	0.31	1.07	1.52	5.7
3	45000	13.05	0.19	0.19	58.19	0.27	0.67	0.43	0.19	1.19	1.33	5.71
4	15000	14	0	0	21	0	1	1	1	1	1	6

Table 20: Clusters Analysis on All Variables – HDU

CL	Transit (Mode)			Walking (Mode)		Work		Energy Use	
	Non-Work Miles	%AllTrps	%Non-WorkTrps	%Non-WorkTrips	Non-WorkMiles	Miles-W	Trps_D	Fuel	CO
1	5.6	26.1%	21.4%	21.4%	5.6	0	33.3%	4.5	8.9
2	0	9.1%	0%	0%	2.4	6.3	38.5%	4.7	9.2
3	0	0%	0%	6.5%	1.4	0.5	93%	5.8	10.2
4	0	0.4%	0.5%	6.5%	1.2	1.4	90%	4.7	9.2

Table 20 (cont'd)

CL	SES			Veh Miles		Race		Dependents			Veh-U
	Pincome	D_Prof	Educ	V_Miles	Wk_Miles_T	D_Bl	D_Wh	Inc_Sup	D_Empl	#Child	
1	25000	1	12	28000	0	1	0	1	1	0	1
2	15000	0	14	192029	5.7	1	0	5	1	0	1
3	39736	0.2	13.2	88712	0	0.8	0.2	2.3	0.9	0.9	1.1
4	42000	0.7	15.7	67366	0	1	0	2.4	1	0.2	1.1

Regression Analyses: The Higher Density Urban (HDU) Neighborhood Typology

After looking at the clusters formed, it is imperative that the hypotheses be tested. The following Regression Analyses will test the hypotheses. This analysis is undertaken to reveal the relationships within the neighborhoods. It is not intended to denote causality, nor is it intended for forecasting purposes; rather it should be looked at as a means to understand the complex relationships of socio-economic factors that are significant in impacting travel behavior and the resultant environmental burdens, while controlling for the physical/built environment. The results are discussed below by trip purpose and the tables, tables 21 and 22, present the results by mode of travel:

- The results indicated that there were no linear relationships between socio-economic characteristics and trips taken for work purposes.
- **<u>For the non-work trips</u>** (*see Tables 21 and 22*):
    - The percentage of travel undertaken by <u>walking</u> as the mode had a significant and negative association with *age, education* and whether the respondents were *employed (for wages)* [Hypothesis C]
    - The percentage of travel undertaken by <u>public transit</u> had a significant and negative association with *household income* [Hypothesis B]
    - The percentage of travel undertaken by <u>driving</u> as the mode had a significant and positive association with *household income, education*, whether the respondents were *employed (for wages)* and the *age* of the respondents [Hypothesis A]
    - The total annual miles for trips undertaken by <u>walking</u> had a significant and negative association with *age*, whether the respondents were *employed (for wages)* and years of *education* received [Hypothesis F]

- The total annual miles for trips undertaken by <u>public transit</u> had a significant and negative association with the respondents' *age* and whether the respondents were *employed (for wages)*[Hypothesis E]
- The total annual miles for trips undertaken by <u>driving</u> had a significant and positive association with *household income* and whether the respondents were *employed (for wages)* [Hypothesis D]

- **<u>For all trips</u>** (*see Tables 21 and 22*):
  - The percentage of travel undertaken by <u>walking</u> as the mode had a significant and negative association with *age, education* and whether the respondents were *employed* (for wages) [Hypothesis C]
  - The regression results showed that there was no linear relationship between socio-economic characteristics and all trips by transit [Hypothesis B]
  - The percentage of travel undertaken by <u>driving</u> as the mode had a significant and positive association with the number of *dependent children*, *household income*, *employment (for wages)* and *age* of the respondent [Hypothesis A]
  - The total annual miles for trips undertaken by <u>walking</u> had a significant and negative association with years of *education* received and the *age* of the respondent [Hypothesis F]
  - The total annual miles for trips undertaken by <u>public transit</u> had a significant and negative association with the *age* of the respondent [Hypothesis E]
  - The total annual miles for trips undertaken by <u>driving</u> had a significant and positive association with *household income* and whether the respondents were *employed (for wages)* [Hypothesis D]

Table 21: HDU Regression results - Mode

Variable	Driving Trips			Transit Trips			Walking Trips		
	Work	Non-Work	All	Work	Non-Work	All	Work	Non-Work	All
Constant	-21.621	-116.859	**-99.676***	74.337	**60.072****	**55.727***	47.284	**156.787*****	**143.949*****
# Dependant Children	9.388	6.250	**8.527****	-3.204	-2.691	-3.631	-6.185	-3.559	-4.895
Dummy_Black	-18.197	7.920	-5.206	10.147	1.518	2.128	8.050	-9.437	3.078
Dummy_White	-15.381	16.135	3.443	0.337	3.487	1.671	15.043	-19.622	-5.114
Education	12.445	**27.528***	23.371	-17.428	-2.694	-0.618	4.983	**-24.834***	**-22.753***
Dummy_Employed	19.237	**22.187*****	**20.012*****	-12.481	-5.238	-2.378	-6.756	**-16.949*****	**-17.634*****
Hshld_Income	3.244	**6.249***	**6.313***	-0.197	**-3.914****	**-3.794****	-3.047	-2.335	-2.519
Age	0.504	**0.613*****	**0.691*****	-0.223	-0.078	-0.108	-0.282	**-0.535*****	**-0.583*****
R^2	.078	.193	.181	.063	.080	.049	.049	.144	.158
Adj. R^2	-.013	.158	.146	-.029	.041	.009	-.045	.108	.122
N	79	172	173	79	172	173	79	172	173

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

Table 22: HDU Regression results – Annual Miles

Variable	Driving Miles			Transit Miles			Walking Miles		
	Work	Non-Work	All	Work	Non-Work	All	Work	Non-Work	All
Constant	-7.871	-4.067	-4.102	7.429	**8.989****	**10.079****	6.620	**13.899*****	**13.147*****
# Dependant Children	-0.110	0.185	0.429	-0.440	0.090	-0.089	**-1.172*****	-0.168	-0.464
Dummy_Black	1.585	-0.833	-0.396	0.583	0.536	0.740	0.013	-0.976	-0.887
Dummy_White	-0.197	-0.261	-0.006	0.295	0.918	0.818	-0.495	-1.405	-1.470
Education	2.164	0.825	0.277	-1.865	-1.188	-1.715	-1.475	**-3.253*****	**-2.848****
Dummy_Employed	-0.651	**1.458*****	**2.087*****	-1.121	**-0.869***	-0.586	-0.137	**-0.964****	-0.534
Hshld_Income	0.895	**0.736*****	**0.820*****	0.071	-0.303	-0.234	0.054	0.100	0.128
Age	**-0.064***	0.007	0.009	-0.034	**-0.034****	**-0.043*****	-0.026	**-0.056*****	**-0.064*****
R^2	.102	.203	.278	.068	.086	.086	.104	.145	.122
Adj. R^2	.013	.169	.247	-.024	.047	.047	-.016	.109	.084
N	79	172	173	79	172	173	79	172	173

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

Table 23: HDU Regression results – Vehicle Characteristics

	Vehicle			Annual Environmental Burdens	
	Veh-All	Veh_Year	Veh_Cyl	Fuel Consumption	CO Emissions
Constant	-1.605	**1965.85*** **	**4.482** **	**-7.469** **	-7.067
# Dependant Children	-.013	0.122	0.014	**0.388***	**0.627****
Dummy_Black	**-1.323** **	-0.794	0.974	**2.819****	**3.351***
Dummy_White	-0.978	-3.838	0.668	**2.956****	**3.561***
Education	0.411	**6.181** *	0.077	**2.304*****	**3.355*****
Dummy_Employed	**0.346** *	1.413	-0.177	**0.818** **	**1.127** **
Hshld_Income	**0.297** ***	**1.599** **	0.004	0.278	0.295
Age	-0.006	0.047	-0.011	-0.008	-0.005
R^2	.304	.234	.047	.341	.285
Adj. R^2	.262	.165	-.015	.279	.218
N	125	118	114	83	110

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

- The <u>number of vehicles owned</u> by the household had a significant and positive association with *household income* and whether the respondent was *employed (for wages),* and a negative association with whether the respondent was *black* (*see Table 23*) [Hypothesis H]
- For those respondents that have access to and use a private vehicle for any part of their travel activity, the <u>year of the vehicle</u> used for travel had a significant and positive association with the *household income* and the number of years of *education* received (*see Table 23*) [Hypothesis G]
- For those respondents that have access to and use a private vehicle for any part of their travel activity, the <u>annual fuel consumption</u> was significantly and positively associated with the number of *dependent children,* whether the respondents were *black,* whether the respondents were *white,* years of *education* and whether the respondents were *employed (for wages)* (*see Table 23*) [Hypothesis D]
- For those respondents that have access to and use a private vehicle for any part of their travel activity, the <u>annual carbon monoxide emissions</u> was significantly and positively associated with the number of *dependent children,* whether the respondents were *black,* whether the respondents were *white,* years of *education* and whether the respondents were *employed (for wages)* (*see Table 23*) [Hypothesis D]

The above analyses results show a clear distinction in the socio-economic characteristics and how they impact travel behavior and environmental burdens. For all trips other than work based trips, socio-economic variables such as household income, employment status (whether employed for wages), and age of the respondent came out as having a significant impact on travel behavior. There were also less often, but significant impacts of education and race (whether the respondent was African American) on travel behavior, vehicle ownership and vehicle characteristics. With only a third of the respondents being employed, travel to work regressions did not show significant goodness-of-fit results. Also, given the fact that there was a small percentage of respondents traveling by modes other than driving to their different destinations, the "percent trip" variables – those showing mode of travel, had non-normal distributions even after transformations (and thereby were kept to their original, untransformed states). The regressions for transit trips, even though they were significant, should be viewed with caution as the dependent variable as well as the residuals were not typically normally distributed and that would imply biased results. Even so, the annual distances driven, fuel consumption and carbon monoxide emission variables were successfully transformed and regression results were significant.

In order to provide further and more textured insight into travel behavior by socio-economic characteristics, a breakdown is provided of the urban neighborhoods by income tertiles, allowing a further exploration into the variation of travel behavior by class.

A Discussion by Income Groupings: The Higher Density Urban (HDU) Neighborhood Typology

Table 24 shows a disaggregation of the respondents of the urban neighborhoods into three groups: those within the lowest one-third of the household income range, those that fall into the middle one-third of the income range and those that have a household income that is in the highest one-third of household incomes.

Table 24: HDU Respondents split into three Household Income groups

Household Income	*Count*	*Percentage*
\$5,000 to \$45,000 (Low Income Range)	161	80%
>\$45,000 to \$90,000 (Middle Income Range)	31	15%
>\$90,000 to \$135,000 (Upper Income Range)	9	5%
Total	201	100%

Table 24 shows that within the HDU typology, there is a heavy concentration of respondents in the lowest income grouping. About 80% of the respondents fall in the lowest income category, while only 5% fall in the highest household income category. This also sheds more light on the figures in table 11 that show the mean values for various variables. The mean household income for the respondents in these neighborhoods is \$30,423, which falls in the lowest third of the income range in these neighborhoods. This stark divide is helpful in understanding the characteristics and behavior of the respondents in the different income groups.

Table 25 (below) shows that the lowest income range, with 80% of the population, has access to less than one car per household, and those that do have access to a car, have older cars (10 years old on average). The highest earning, 5% of the respondents, have access to just under 2 cars per household and have newer cars (7 years old on an average). The table on demographic characteristics (table 24) shows that there is not a difference in the age of the respondents across the income classes, nor a difference in the number of dependents in the household. There is a visible difference, however, in the years of education received. The respondents in the lowest income range have an average of 13 years of education (completed high school), while the ones in the highest income range have an average of 16 years of education (college graduates).

Table 25: HDU Vehicle Ownership

	Income Range		
	Low	Middle	Upper
Vehicles for you	0.8	1.1	1.3
Vehicles for all in household	0.8	1.6	1.8
Vehicle Year	1998	2002	2002

Table 26: HDU Demographic Characteristics

	Income Range		
	Low	Middle	Upper
Age	51.1	50.7	51
Education	12.5	14.5	15.8
Number of people the Income Supports	2.3	2.5	2.4
Number of children living at home	1.0	0.6	0.9

Table 27: HDU Mode of Travel Based on Usual Weekly Travel Patterns

	Income Range		
	Low	Middle	Upper
% WorkTrips by Walk	16	12.6	0
% WorkTrips by Transit	16.5	7.7	0.5
% WorkTrips by Drive	67.6	79.7	99.5
% Non-Work Trips by Walk	27.4	12.2	12.2
% Non-Work Trips by Transit	9.2	3.1	6.9
% Non-Work Trips by Drive	63.4	84.7	80.9
% All Trips by Walk	26.8	13.7	6.8
% All Trips by Transit	10.7	4.4	7.1
% All Trips by Drive	62.5	81.9	86.1

Table 27, depicting the mode of travel by the income groupings paints an interesting picture. For work trips, the respondents in the upper income category rely solely on driving as the mode of travel, while those in the lowest income range conduct two-thirds of their trips to work by driving. Those in the lowest income category undertake about 16% of work-trips by walking and use transit for about another 16% of work-trips.

For non-work trips, the upper income range respondents use driving as the mode for about 81% of the trips. These respondents walk for 12% of their trips and use transit for 7% of their trips. This remains quite a different travel behavior pattern from the lowest income category residents. Respondents in the lowest income category use driving for about 63% of the trips to non-work destinations, while they use transit for 9% and walk for another 28% of their trips. Again, this is for non-work trips specifically.

The reliance of the upper income residents on the car for all of their work trips might have something to do with where their jobs are located. Looking at the table on annual average distances to end-point destinations, we see that these residents travel over four thousand eight hundred miles on average per year to work destinations in their cars, while the lowest income range residents travel about one fourth of those miles per year in their vehicles. This difference is telling as it may suggest that the upper income residents have jobs further from their residence locations. The longer distances among the upper income grouping imply that many are likely driving into the Detroit CBD or into the suburbs for their employment. The lowest income range residents either do not have the educational qualifications or access to vehicles to accept the jobs in the CBD or outside the city limits. Many of the residents within the lowest income category are also unemployed. Another important travel pattern to recognize is that all three income groups travel further distances to work than to non-work destinations, thereby exercising their choice for different and closer available locations and products in an urban environment characterized by higher accessibility, density and connectivity.

Lastly, the upper income HDU residents travel over 3.5 times the average annual distance to end-point locations that the lowest income residents travel for all purposes by car. Consequently, they have over 2.5 times the annual fuel consumption and the annual carbon emissions as that of the lowest income range residents. The wealthier respondents have newer cars and that might be a factor in the lower proportional emissions. In any case, the upper income residents have vehicles and travel patterns that result in greater environmental burdens.

Table 28: HDU Average Annual Miles to End-Point Destinations by Trip Purpose Based on Usual Weekly Travel Patterns

	Income Range		
	Low	Middle	Upper
Annual Miles for WorkTrips by Walk	157.7	821.0	0.0
Annual Miles for WorkTrips by Transit	238.5	644.1	0.0
Annual Miles for WorkTrips by Drive	1209.3	3172.4	4809.1
Annual Miles for Non-Work Trips by Walk	199.1	522.6	213.5
Annual Miles for Non-Work Trips by Transit	214.2	615.7	219.0
Annual Miles for Non-Work Trips by Drive	1036.6	2590.3	2179.6
Annual Miles for All Trips by Walk	259.8	1097.3	213.5
Annual Miles for All Trips by Transit	305.9	1066.5	219.0
Annual Miles for All Trips by Drive	1501.7	4811.0	5385.6

Table 29: HDU Average Annual Environmental Burdens Based on Usual Weekly Travel Patterns*

	Income Range		
	Low	Middle	Upper
Annual Fuel Consumption (gallons)	221	484.8	588.6
Annual Carbon Monoxide Emissions (grams)	20140.8	38212.2	51464.8

*The environmental burdens calculations are a result of both end- and return-destination trips.

Discussion

The analyses of the urban neighborhoods reveal a number of important characteristics in travel patterns within this neighborhood typology. There is a heavy concentration of low income African American residents in these neighborhoods. However, there are a few residents of 'other' races that live here and there are also some residents with higher personal and household income levels, at least relative to the neighborhood averages. Holding the built environment constant, a number of marked differences in travel behavior of residents are recognized by socio-economic characteristics. It was thought that these socio-economic characteristics alone would account for the differences in travel behavior, but as the analysis revealed, there were other variables that had significant associations with travel. Age is one of those conditions that came up often in the regressions as significantly affecting travel behavior, even though it is not included as a socio-economic variable. It is understandable that the older you get, the more you would travel by a private vehicle rather than public transit or walking. Older residents tend to choose a more comfortable mode of travel as they are unable to walk longer distances and/or take public transit.

The main revelation is that even the very few residents with a higher level of socio-economic characteristics have a remarkably different travel pattern. They have jobs that are further away, perhaps in the Detroit CBD or outside the city, and have and exercise the option to travel by their vehicles for most trips. The cluster analysis singled out some of these residents as 'outliers', however as mentioned earlier, this is a legitimate class of residents. This is also precisely the reason why the mode travel variables were skewed but still left as is for the regressions. Respondents in the lowest income grouping have jobs that are closer and are more restricted by income to travel more often by other means of transportation than the car for their work trips. Many of these residents are also simply unemployed. This is also reflected in the fact that they have access to fewer cars and so they are relegated to travel to nearer destinations. These residents travel lesser distances by car when they need to travel to non-work destinations, but these figures are significantly below those of the higher income residents.

Another characteristic that is evident in this neighborhood is that the higher income residents are responsible for a higher amount of pollutants. Given that they travel further and more often in their vehicles, they consume the expected higher levels of fuel, emit higher levels of carbon monoxide emissions and consume more fuel. Hence, a class factor emerges in the selection of vehicle choices, as we see the upper income range residents travel more via their cars, consume more fuel and are responsible for more emissions than are the lower and middle income range residents living in the same built environment. At the same time, middle income respondents in the urban neighborhoods—while consuming less petroleum and emitting fewer CO emissions than the upper income respondents—consume more fuel and maintain higher CO emissions than the lowest income respondents. This is supported by both the regression analyses and the analyses of the income sub-groups.

Higher Density Suburban – Ann Arbor and Birmingham Neighborhoods

In terms of the urban built environment, the spatial structure of the neighborhoods, the HDS neighborhoods are similar to the HDU neighborhood typology. These are relatively high density neighborhoods for the Michigan context, their road networks are based on the gridiron street pattern, and the neighborhoods are characterized by mixed land uses. Looking at the socio-economic characteristics of residents in the HDS neighborhoods, however, they are predominantly white, and they have higher incomes and greater education levels than the residents of the HDU neighborhoods. So in essence, the built environment characteristics of the HDS neighborhoods are similar to the urban neighborhoods, while the socio-economic characteristics of these residents are similar to the HDS neighborhoods. Table 30 has some descriptions of the categorical variables used in the analyses:

Table 30: HDS Breakdown of categorical variables

Variable	Higher Density Suburban	
	Number	*Percent*
RACE		
White	359	93.7
Non White	24	6.3
Black	7	1.8
Non-Black	376	98.2
Total	383	100
OCCUPATION		
Employed (for wages)	250	63.8
Non-Employed	142	36.2
Total	392	100

The above table identifies the low number of African American respondents in these neighborhoods (7 respondents who make-up 1.8% of the total number of respondents). However, there is a greater amount of 'other' races mixed in these neighborhoods when compared to the HDU neighborhoods. The HDS neighborhoods had 93.7% white respondents, 1.8% African American respondents and 4.5% of the respondents belonged to 'Other' races. Two thirds of the respondents were employed for wages. Only a small part of these unemployed respondents can be attributed to the student population of Ann Arbor, since the average age of the respondents was about 51 years old. A significant portion of the unemployed consist of retired residents and stay at home parents, since the number of dependents (children living at home) was close to 1 and the income of the respondents supported 2.4 people on average. The table below gives the descriptive statistics for the variables assessed for this neighborhood typology. It should be recognized that these variables are the same as the variables analyzed for the HDU neighborhoods.

Table 31: HDS Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Std. Dev.
VehYou	376	0	6.0	1.24	0.64
VehAll	334	0	6	1.95	0.86
VehYear	384	1964	2008	2001.98	5.05
VehCyl	369	4	8	5.23	1.26
VehMiles	377	0	315000	62672.20	52165.86
Age	391	19	90	50.99	16.20
Educ	389	12	19	17.08	2.29
Num_Child	377	0	3	0.54	0.90
Inc_Supports	377	0	8.0	2.44	1.35
PIncome	356	5000	155000	62359.55	44186.48
HIncome	347	5000	155000	96123.92	46665.14
Pct_WorkTrips_W	265	0.00	100.00	16.03	31.00
Pct_WorkTrips_T	265	0.00	100.00	6.66	19.34
Pct_WorkTrips_D	265	0.00	100.00	77.30	37.12
Pct_OptTrips_W	389	0.00	100.00	21.47	27.09
Pct_OptTrips_T	389	0.00	74.47	1.13	6.48
Pct_OptTrips_D	389	0.00	100.00	77.39	28.33
Pct_AllTrips_W	392	0.00	100.00	20.12	25.26
Pct_AllTrips_T	392	0.00	71.43	2.83	9.45
Pct_AllTrips_D	392	0.00	100.00	77.05	27.80
Ann_WorkMiles_W	265	0.00	7040.80	130.68	671.76
Ann_WorkMiles_T	265	0.00	4264.00	64.18	358.51
Ann_WorkMiles_D	265	0.00	17602.00	1926.99	2760.72
Ann_OptMiles_W	391	0.00	4581.20	99.89	298.87
Ann_OptMiles_T	391	0.00	1006.20	9.13	61.21
Ann_OptMiles_D	391	0.00	6749.60	855.59	896.22
Ann_AllMiles_W	392	0.00	7065.50	187.98	639.16
Ann_AllMiles_T	392	0.00	4264.00	52.49	304.52
Ann_AllMiles_D	392	0.00	18502.12	2156.09	2593.39
Ann_Fuel_Consump	355	0.00	925.11	106.31	129.34
Ann_CO_Emissions	356	0.00	77708.90	8870.33	10899.63

* Ann_Fuel_Consump and Ann_CO_Emissions show annual total environmental burdens for travel to end-point destinations.

Cluster Analyses: The Higher Density Suburban Neighborhood Typology

The first analysis performed was the Cluster Analysis. As with the urban neighborhood typology, this analysis was done twice, once using only the demographic variables and the second time including the travel behavior variables. The Cluster Analysis on the HDS neighborhoods with demographic variables only revealed groups that were varied in: 1) household and personal incomes; 2) year of vehicles and the number of miles on the vehicles; 3) the number of vehicles owned; and 4) race (*see Table 32*). With all the variables included in the second Cluster Analysis, the resultant groupings varied a lot more by their travel patterns than their socio economic patterns. Essentially they differed by: 1) the work and non-work trips undertaken by walking and driving; 2) the emissions and fuel consumption patterns; and 3) the use of transit for trips related to work and all trips taken together (*see Table 33*).

For each of the two Cluster analyses, first the clusters with low membership numbers (<4) are discussed, followed by the discussion of the clusters with sufficient membership numbers (>=4).

Table 32: Cluster Analysis on Demographic and Socio-economic Variables - HDS

CL	Employment		Income		Dependants		Veh_Age		Veh_Ownership		Race	
	Empl	Prof	PIncome	HIncome	Inc_Sup	Child	Year	Miles	You	All	Wh	Bl
1	0.7	0.6	71271	108136	2.4	0.5	2005	33380	1.2	1.9	1.0	0
2	0.8	0.6	55482	92831	3.0	1.0	1998	110069	1.1	1.9	1.0	0
3	0.4	0.4	63000	81000	2.2	0.4	2000	88825	1.2	1.8	0	1.0
4	0.6	0.5	66000	105500	2.8	0.4	2003	49740	2.7	3.6	0.9	0

Table 33: Cluster Analysis on All Variables - HDS

CL	Non-Work Trips			Energy Use		Transit (Mode)		Work	
	%-Walk	%-Drive	Non-WorkMile_W	Fuel	CO	%WrkTrps	%AllTrps	%Trp_W	%Trp_D
1	32.9	67.1	3.9	4.9	9.3	1.4	0.4	17.0	81.6
2	55.7	44.2	4.7	4.2	8.7	13.7	6.9	27.4	58.9
3	18	82	1.3	4.6	9.1	3.2	1.5	19.5	77.4
4	13.2	86.8	1.1	4.1	8.5	0.7	0.5	16.9	82.4
5	41.7	58.3	2.7	3.4	7.9	76.7	40.5	0	23.3
6	0	100	0	4.4	8.7	0	0	0	100
7	22.2	77.8	1.3	3.3	7.7	70	40.5	17.8	12.2
8	44.1	45	5	3.6	8.0	30.6	17.7	30.6	38.9

Table 33 (cont'd)

CL	SES			Non-Work Trips by Transit		Dependents		Veh_Age	
	Admin	Educ	Veh_All	Miles	%Trips	Inc_Supp	Child	V_Year	V_Miles
1	0	18.4	2.1	0	0	2.7	0.7	2002	69876
2	0	18	1.7	1.1	0.1	2.3	0.7	1999	108000
3	0.8	14.6	2.1	0	0	2.5	0.5	2004	52097
4	0	17.9	1.9	0	0	2.9	0.9	2003	57236
5	1	15.3	2	0	0	2	0	2001	63667
6	0	14.3	1.5	0	0	1.5	0	2000	63000
7	0	18	1.7	0	0	1.7	0	1997	156667
8	0.3	18.5	1.8	4.6	10.9	3.2	1	2000	77667

Table 33 (cont'd)

CL	Race			Gender/Laborer	
	Wh	Bl	D_Empl	Labor	Gender
1	1	0	0.8	0	0.6
2	0	1	0.7	0	0.3
3	1	0	1	0	0.2
4	0.9	0	1	0	0.4
5	1	0	1	0	0.7
6	1	0	1	1	0.8
7	0.7	0	0.3	0	0.3
8	1	0	1	0	0.3

The results of the analysis on this neighborhood type, while in many ways producing similar outcomes as in the urban neighborhood grouping, also revealed some differences. These differences are likely attributable to the built environment characteristics of the higher density suburban neighborhoods, which have a richer mix of amenities within and in proximity of the neighborhoods, giving the residents the option of driving, using public transit or walking in reaching various destinations.

For the K-Means cluster analysis with 4 groups done on the socio-economic variables, none of the clusters had a deficient number of members. Results are presented below:

- Cluster 1 identified a group of all white respondents who had higher than average personal and household incomes. Their vehicles were the newest (4 years old on an average) with the fewest miles on the vehicles.
- Cluster 2 identified a group of all white respondents who had the lowest personal incomes (average was $55,482), had more dependents, older cars (11 years old on an average) and higher mileage on the vehicles.
- Cluster 3 identified a group of all African American residents who had below average household incomes, older cars (9 years old on average) with higher mileage on the cars.
- Cluster 4 identified a majority white group of residents that had high vehicle ownership and higher than average household incomes.

The Cluster Analysis with all variables (demographic and travel behavior) resulted in 8 clusters, with three of them having very low membership numbers.

- <u>Cluster 2</u> identified a group of 3 members that are African American, two females (who are employed for wages) and a male. This group is highly educated, has older cars (10 years old on an average) and therefore higher mileage on their vehicles. What is unique about this group is the usage of walking as a mode of travel. More than half of their non-work trips and about 27% of their work trips are done by walking. Consequently, driving is chosen less frequently as a mode of travel.
- <u>Cluster 5</u> also had 3 members. This cluster identifies a group of 2 males and 1 female white respondent who are all employed in the Administrative and Service professions. Their unique characteristic is that they use transit for two-thirds of their trips for work. They do not use transit for non-work purposes, rather they walk about 42% of the time for their non-work trips. Consequently, they consume less fuel and emit fewer pollutants.
- <u>Cluster 7</u> is a group of mostly females, the majority of who are not employed for wages. They are extensive users of transit for work purposes and walk for 1/5 of their non-work trips. They have older cars with very high mileage on the vehicles, however, they consume less fuel and emit fewer pollutants.
- <u>Cluster 1</u> is a group of all white respondents, most of them employed for wages and they are highly educated. This group has over 2 vehicles in the household, and the vehicles are extensively used for travel (over 80% of work trips and over 67% of non-work trips are by driving). Consequently, this group is responsible for the highest levels of fuel consumption and they emit the highest levels of carbon monoxide.

- <u>Cluster 3</u> is a group of white respondents, mostly females who are employed for wages in the Administrative and Service professions. This group drives most of the times to their destinations, while they use walking as a mode for about a fifth of their work and non-work trips. Consequently, they are the second highest fuel consumers and polluters.
- <u>Cluster 4</u> is a group of white respondents, all of them highly educated and employed for wages. This group has a higher number of dependents at home (number of people the income supports and the number of children under the age of 18). They do not use transit for their trips, they walk to some of their non-work trips, but they mostly drive for the majority of their trips, the all-purpose trips. They have newer cars with fewer miles on them and are average polluters and fuel consumers.
- <u>Cluster 6</u> is a relatively small group of white males that have lower levels of education and are all employed as laborers. This group of people have no children living at home, and their unique characteristic is that they drive to all of their trips (work and non-work), yet they are not the highest polluters and fuel consumers.
- <u>Cluster 8</u> is a group of white mostly females who are highly educated and have a higher number of dependents that their income needs to support. This group uses transit for 10% of their non-work trips and over 30% for their work trips, and they walk for just under 50% of their non-work trips. All this suggests that they drive less and consequently they are low consumers of fuel and are low emitters of pollutants.

Regressions Analyses: The Higher Density Suburban Neighborhood Typology

The variables in this file were also transformed as necessary to get their distributions as close to normal as possible. Yet, in this file too, the range of percent traveled by different modes was skewed and no transformation made those better. This is why they were kept as is for the analyses. Appendix F shows the before and after transformation statistics. In testing the hypotheses, the regression analyses showed the following results, discussed below by trip purpose and presented in tables 34 and 35 by mode of travel:

- **<u>For work trips</u>** (*see Tables 34 and 35*):
    - There was no linear relationship between socio-economic characteristics and walking to work trips [Hypothesis C]
    - The percentage of travel undertaken by <u>public transit</u> had a significant and negative association with *household income* [Hypothesis B]
    - The percentage of travel undertaken by <u>driving</u> as the mode had a significant and positive association with *household income* and whether the respondents were *employed (for wages)* [Hypothesis A]
    - The analysis on the total annual miles for trips undertaken by <u>walking</u> did not show any linear relationships [Hypothesis F]
    - The total annual miles for trips undertaken by <u>public transit</u> had a significant and positive association with whether the respondent was *black.* [Hypothesis E]
    - The total annual miles for trips undertaken by <u>driving</u> had a significant and positive association with whether the respondent was *employed (for wages)* and a negative association with the *age* of the respondent [Hypothesis D]
- **<u>For the non-work trips</u>** (*see Tables 34 and 35*):

- The percentage of travel undertaken by <u>walking</u> as the mode had a significant and negative association with *household income* [Hypothesis C]
- The percentage of travel undertaken by <u>public transit</u> had a significant and negative association with *household income* [Hypothesis B]
- The percentage of travel undertaken by <u>driving</u> as the mode had a significant and positive association with *household income.* [Hypothesis A]
- This analysis showed no linear relationships between annual miles <u>walked</u> to non-work destinations and socio-economic characteristics [Hypothesis F]
- This analysis showed no linear relationships between annual miles by <u>public transit</u> to non-work destinations and socio-economic characteristics [Hypothesis E]
- The total annual miles for trips undertaken by <u>driving</u> had a significant and positive association with *household income* and a negative association with whether the respondent was *black* [Hypothesis D]

* **<u>For all trips</u>** (*see Tables 34 and 35*):
  - The percentage of travel undertaken by <u>walking</u> as the mode had a significant and negative association with *household income* [Hypothesis C]
  - The percentage of travel undertaken by <u>public transit</u> had a significant and negative association with *household income* [Hypothesis B]
  - The percentage of travel undertaken by <u>driving</u> as the mode had a significant and positive association wit*h household income* [Hypothesis A]
  - The total annual miles for trips undertaken by <u>walking</u> had a significant and negative association with the *age* of the respondent [Hypothesis F]

- The total annual miles for trips undertaken by <u>public transit</u> had a significant and negative association with *household income* and the *age* of the respondent [Hypothesis E]
- The total annual miles for trips undertaken by <u>driving</u> had a significant and positive association with *household income* and whether the respondents were *employed (for wages)*, and a negative association with the *age* of the respondent [Hypothesis D]

Table 34: HDS Regression results - Mode

Variable	Driving Trips			Transit Trips			Walking Trips		
	Work	Non-Work	All	Work	Non-Work	All	Work	Non-Work	All
Constant	32.564	**58.614*** **	**50.556*** **	**39.099*** **	4.090	**14.517*** **	28.337	**37.296** **	**34.927** **
# Dependant Children	2.053	-0.800	0.117	-1.995	0.604	-0.582	-0.058	0.196	0.466
Dummy_Black	4.144	-5.991	6.948	-3.362	-0.643	-2.000	-0.782	6.634	-4.948
Dummy_White	9.301	0.639	3.966	-7.127	1.466	-1.540	-2.173	-2.105	-2.426
Education	-0.172	-1.101	-0.992	-0.475	0.025	0.074	0.647	1.077	0.917
Dummy_Employed	**19.638** **	2.491	3.463	-2.132	-0.739	0.254	**-17.507** **	-1.753	-3.717
Hshld_Income	**0.072** **	**0.096*** **	**0.092*** **	**-0.050** **	**-0.019*** **	**-0.032*** **	-0.023	**-0.077*** **	**-0.060*** **
Age	-0.054	0.131	0.177	0.023	0.024	-0.030	0.031	-0.155	-0.147
R^2	.080	.082	.085	.078	.064	.079	.040	.065	.049
Adj. R^2	.050	.061	.064	.048	.043	.058	.009	.043	.027
N	224	312	314	224	312	314	224	312	314

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

Table 35: HDS Regression results – Annual Miles

Variable	Driving Miles			Transit Miles			Walking Miles		
	Work	Non-Work	All	Work	Non-Work	All	Work	Non-Work	All
Constant	**5.333***	**5.094***	**5.556***	**2.773**	0.190	**2.339**	1.922	**3.190**	**3.604**
# Dependant Children	0.000	-0.146	-0.122	-0.339	0.102	-0.170	-0.031	0.076	-0.041
Dummy_Black	0.861	**-1.231***	0.198	**2.494**	0.441	1.339	1.720	-0.158	0.440
Dummy_White	-0.581	0.374	0.027	0.027	0.348	0.169	-0.467	0.094	0.005
Education	-0.070	0.011	0.013	-0.021	0.025	0.010	0.033	0.073	0.081
Dummy_Employed	**2.908***	-0.171	**0.904***	-0.232	-0.047	0.200	-0.554	-0.387	-0.069
Hshld_Income	0.004	**0.004***	**0.004***	-0.003	**-0.002***	**-0.005***	0.000	**-0.003***	-0.003
Age	**-0.040***	-0.007	**-0.010***	-0.011	0.001	**-0.013***	-0.006	**-0.024**	**-0.033***
R^2	.143	.061	.165	.073	.032	.067	.025	.036	.046
Adj. R^2	.115	.039	.146	.043	.010	.045	-.006	.014	.024
N	224	313	314	224	313	314	224	313	314

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

Table 36: HDS Regression results – Vehicle Characteristics

	Vehicle			Annual Environmental Burdens	
	Veh-All	Veh_Year	Veh_Cyl	Fuel Consumption	CO Emissions
Constant	**-2.064***	**1999.812***	**4.989***	**2.768***	**6.807***
# Dependant Children	-0.120	0.235	0.187	-0.047	-0.064
Dummy_Black	-0.310	-0.642	-0.749	0.329	0.489
Dummy_White	-0.121	0.459	-0.227	0.202	0.244
Education	**-0.047***	**-0.221***	**-0.063***	-0.003	0.028
Dummy_Employed	**-0.230***	0.276	**-0.532***	**0.754***	**0.754***
Hshld_Income	**0.005***	**0.021***	**0.004***	**0.002****	0.002
Age	**-0.007***	-0.017	**0.009***	-3.430E-5	0.000
R^2	.142	.161	.144	.124	.087
Adj. R^2	.119	.139	.121	.101	.064
N	270	306	296	284	285

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

- The number of vehicles owned by the household had a significant and positive association with *household income* and a negative association with the *age* of the respondent, the years of *education* received, and whether the respondent was *employed (for wages)* (*see Table 36*) [Hypothesis H]
- For those respondents who have access to and use a private vehicle for any part of their travel activity, the year of the vehicle used for travel had a significant and positive association with the *household income* and a negative association with the years of *education* received (*see Table 36*) [Hypothesis G]
- For those respondents who have access to and use a private vehicle for any part of their travel activity, the engine size of the vehicle used for travel had a significant and positive association with the *household income,* and the *age* of the respondent, and a negative association with the years of *education* received, and whether the respondents were *employed (for wages)* (*see Table 36*) [Hypothesis I]
- For those respondents who have access to and use a private vehicle for any part of their travel activity, the annual fuel consumption was significantly and positively associated with *household income* and whether the respondents were *employed (for wages)* (*see Table 36*) [Hypothesis D]
- For those respondents who have access to and use a private vehicle for any part of their travel activity, the annual carbon monoxide emissions was significantly and positively associated with whether the respondents were *employed (for wages* (*see Table 36*) [Hypothesis D]

The above regression analyses show a class dimension to some of the travel patterns and environmental burdens (as was the case with the urban neighborhoods). The difference in these higher density suburban neighborhoods was that race came up as significant in a few of the regressions, which is interesting and telling. Although the number of African American respondents was very low, still the fact that they came out as significant in some travel behavior was insightful. The results show that African Americans travel further distances annually to work by transit and they are more likely to travel shorter distances annually to non-work destinations by car. However, both those regression results must be viewed with caution as the dependent variable, annual miles traveled, had skewed distributions (even after transformations). This would imply that the results are biased. The regressions on mode of travel showed that walking to work trips was not significant. However, the transit trips to all three destination types (work, non-work, and all) should be viewed with caution as these dependent variables were highly skewed. As such the associations might not be robust. Similarly, the regressions on annual miles to non-work trips by transit and to work and non-work trips by walking showed insignificant associations. The variable for annual miles to non-work trips by transit, even after transformations, was highly skewed and as such this regression result is understandable. However, the variables for annual miles by walking to work and non-work trips are only slightly skewed and therefore the insignificant regression results show more a case of non-significant linear associations, than the result of skewed variable distributions. In order to get a qualitative look at the range of travel behavior and environmental burdens, the following section explores this behavior by class of income.

A Discussion by Income Groupings: The Higher Density Suburban Neighborhood Typology

Similar to the analysis of the urban neighborhoods, a breakdown of the respondents of the higher density suburban neighborhoods into income tertiles (see table 37) will allow for further texture into the analysis of the socio-economics of travel behavior and resulting impacts on gasoline consumption and CO emissions.

Table 37: HDS Respondents split into three Household Income Groups

Household Income	*Count*	*Percentage*
$5,000 to $50,000 (Low Income Range)	66	19%
>$50,000 to $100,000 (Middle Income Range)	114	33%
>$100,000 to $155,000 (Upper Income Range)	167	48%
Total	347	100%

A visible difference emerges as we look at the income breakdown in the HDS neighborhoods, see table 35. Almost half of the respondents (48%) fall into the highest one-third category of household income and only 19% fall into the lowest one-third household income category. The average household income for all the respondents in this neighborhood type was $95,920. Tables 38 and 39 below give a more detailed look at the characteristics of these three groups of respondents within the higher density suburban neighborhoods.

Table 38: HDS Vehicle Ownership

	Income Range		
	Low	Middle	Upper
Vehicles for you	0.9	1.3	1.3
Vehicles for all in household	1.4	1.9	2.2
Vehicle Year	2000	2001	2003

Table 39: HDS Demographic Characteristics

	Income Range		
	Low	Middle	Upper
Age	50.9	49.3	49.7
Education	15.6	17.0	17.8
Number of people the Income Supports	1.6	2.3	3.0
Number of children living at home	0.2	0.4	0.8

Tables 38 and 39 show that the upper income group of respondents has newer and more vehicles for use by the respondents themselves and by everyone else in the household. Although there is not much of a difference in the ages of the respondents between the three income groups, the education received (as would be expected) increases as the income of the sub-grouping increases. Also relevant is that the number of dependents increases with household income. The upper income range residents have about 3 people that their income supports, and a child under the age of 18 years living at home, while the lowest income range respondents support less than 2 people on their household income, and most of these households do not have any children under the age of 18 years living at home.

Table 40: HDS Mode of Travel Based on Usual Weekly Travel Patterns

	Income Range		
	Low	Middle	Upper
% WorkTrips by Walk	28.9	13.2	14.9
% WorkTrips by Transit	21.1	5.8	3.5
% WorkTrips by Drive	50.0	81.0	81.6
% Non-Work Trips by Walk	32.1	20.0	19.0
% Non-Work Trips by Transit	3.7	0.4	0.6
% Non-Work Trips by Drive	64.2	79.6	80.4
% All Trips by Walk	29.3	19.0	18.1
% All Trips by Transit	8.4	2.0	1.6
% All Trips by Drive	62.3	79.1	80.3

Table 41: HDS Average Annual Miles to End-Point Destinations by Trip Purpose Based on Usual Weekly Travel Patterns

	Income Range		
	Low	Middle	Upper
Annual Miles for WorkTrips by Walk	74.9	47.1	228.4
Annual Miles for WorkTrips by Transit	126.0	35.2	77.5
Annual Miles for WorkTrips by Drive	478.9	1963.6	2198.7
Annual Miles for Non-Work Trips by Walk	146.3	101.7	67.8
Annual Miles for Non-Work Trips by Transit	30.5	6.6	3.6
Annual Miles for Non-Work Trips by Drive	789.2	858.1	896.7
Annual Miles for All Trips by Walk	189.4	136.3	233.1
Annual Miles for All Trips by Transit	103.1	32.4	59.9
Annual Miles for All Trips by Drive	1064.9	2300.4	2484.8

Tables 40 and 41 above show the travel patterns of the residents within each income range. As far the mode of travel is concerned, the middle and upper income range residents behave in a similar manner while those in the lowest income range have a clear difference in their mode choice. For work trips, the lower income residents walk twice as many times as the middle and upper income residents and they use public transit 7 times more than the residents in the middle and upper income groupings.

The non-work trips do not show such drastic differences, yet variations still do exist. The lowest income group residents walk for 32% of their non-work trips, while the upper income residents walk for 19% of their non-work trips. Transit choice is more polarized, with the lowest income residents using transit for 3.6% of the non-work trips while the upper income residents use it for less than 1% of their non-work trips.

In examining annual miles traveled to end-point destinations by different modes of transport, table 39 shows an interesting trend. The middle income residents and the upper income residents do not travel similar distances necessarily (even though their mode choice was similar). The upper income residents travel longer distances by walking and public transit than the middle income residents. Another interesting point to recognize is that upper income residents walk longer annual distances to end-point locations, when compared to even the lower income grouping.

The lowest income residents walk most and travel longer distances by walking when compared to the respondents in the middle income groupings. Travel by car shows similar difference in travel patterns by class, with the upper income residents travelling about 4.5 times the amount that the lower income residents travel to work annually by car.

Similar to the urban neighborhoods, this analysis shows that upper income residents travel further from their suburban neighborhoods for work purposes by car. Non-work trips show a lesser difference. The upper income residents travel only slightly more in distance that the lower income residents do for non-work trips, and as a result, the total annual distance traveled for <u>all</u> trip purposes shows the upper income residents travelling about 2.3 times the distance that the lower income residents do by car.

Table 42: HDS Average Environmental Burdens Based on Usual Weekly Travel Patterns *

	Income Range		
	Low	Middle	Upper
Annual Fuel Consumption (gallons)	115.4	216.4	261.6
Annual Carbon Monoxide Emissions (grams)	9652.6	19058.6	21172.2

*The environmental burdens calculations are a result of both end- and return-destination trips.

The environmental burdens table shows a consistent trend. Since upper income residents travel about 2.3 times the distance that lower income residents travel, by car specifically, they consume about 2.3 times the fuel and emit about 2.2 times the pollutants. Similar to the environmental burden patterns among HDU neighborhoods, the wealthier drive more, consume more gasoline, and are responsible for higher amounts of pollutant emissions, all while controlling for built environment characteristics.

Discussion

What we see from the analyses on the higher density suburban neighborhoods is a tempered variation of travel that was evident in the urban neighborhoods. The two neighborhoods in the HDS grouping do not belong to the same city, nor are they geographically adjacent to each other, but they are grouped into this category due to their similarities in the built environment and their similarities in socio-economic characteristics. These are robust neighborhoods in cities with strong urban cores, at least for a Detroit regional context, a robust land use mix and a connected street system. They are also dynamic and robust neighborhoods within wealthy cities. Both sets of the cluster analyses showed groupings that were primarily based on income, education, employment and travel patterns that consequently affect fuel consumption and emissions.

The regression analyses also brought out the class dimension associated with socioeconomic characteristics, travel, and environmental burdens. Although a few results showed race as a significant factor as well, the analyses led us to accept the hypotheses laid out earlier, that residents with higher socio-economic characteristics travel more by car, consume more gasoline and are responsible for higher amounts of pollutant emissions than those with lower socio-economic characteristics. When controlling for the built environment in these neighborhoods, the difference visible in travel behavior and environmental burdens all point to socio economic characteristics as an important influence; wealthy people travel more by car, travel longer distances by car, consume more gasoline and pollute more. Similar to the results in the urban neighborhood typology, age also gets identified as a significant factor in travel behavior in the higher density suburban neighborhoods. Although it is not a variable that indicates socio economic status, it does affect the probability of using alternate travel modes for various trip purposes. The older population generally prefers traveling by car than walking or taking public transit.

The HDS neighborhood type also revealed that the middle and upper income range respondents had very similar patterns relating to mode of travel for the different trip purposes, but the distance traveled was not that similar. The upper income range respondents walked further distances annually to all trips than the middle income resident grouping. This is interesting as you would expect the upper income group to walk less. This might be the result of the rich amenities in these neighborhoods—or access to rich amenities in the vicinity of these neighborhoods—and the greater opportunities for walking to various necessary destinations. The upper income residents might also be more health conscious and be willing to walk more as part of a healthier lifestyle. While this difference in walking (by the upper and middle income respondents) is evident, it is very small in comparison to the percentage of trips and miles walked annually by the lower income range respondents, with the lower income range respondents walking much more and longer distances for <u>all</u> trip purposes. This is again the class effect at play. The upper income range respondents drove 2.5 times the distances of the lower income range respondents for <u>all</u> trips, a substantial variation in travel patterns.

The ‘tempered’ part in the HDS neighborhoods comes from the fact that in the analysis of the HDU neighborhoods, the respondents in the upper income grouping drove for ten times more trips when compared to the respondents in the lower income grouping. This type of polarized travel pattern is not evident in the HDS neighborhoods, where the upper income residents traveled about 2.3 times the distance, consumed about 2.3 times the fuel and were responsible for about 2.3 times the pollutant emissions. Again, this likely speaks to the availability of richer amenities—and the greater accessibility to daily necessary destinations—in proximate distance within the higher density suburban neighborhoods. However, it does reinforce, once again, the fact that the wealthier drive more and are responsible for higher amounts of environmental burdens than the lower income residents.

Low Density Suburban – Bloomfield Hills and West Bloomfield Neighborhoods

The built environment of the lower density suburban (LDS) neighborhoods is structurally very different from the urban (HDU) and higher density suburban (HDS) neighborhoods. These are the lowest density neighborhoods, they are dominated by single land uses, predominantly residential, and are disconnected, being developed around the curvilinear street system. The socio economic characteristics of the residents also show a less diverse residential base, in terms of class. The incomes are high—and as might be expected given the built environment and incomes, and given the results so far from the analyses—the travel behavior of these respondents is heavily automobile-dependent. Since transit is not prevalent in these neighborhoods (the SMART transportation system has a couple routes that come into the peripheries of these neighborhoods) travel by transit is minimum. Table 43 below shows a breakup of the categorical variables used in the analyses.

Table 43: LDS Breakdown of Categorical Variables

Variable	**Low Density Suburb**	
	Number	*Percent*
RACE		
White	281	88.6
Non White	36	11.4
Black	11	3.5
Non-Black	306	96.5
Total	317	100
OCCUPATION		
Employed (for wages)	186	58.1
Non-Employed	134	41.9
Total	320	100

These neighborhoods have a greater mix of residents than the urban or high density suburban neighborhoods. Whites make up about 89% of the residents, African American respondents make up 3.5% and respondents of other' races make up the remaining 7.5% of this neighborhood typology. The increase in the 'other' races reinforces the urban growth theories that suggest that immigrants that come in as highly qualified take up jobs and residence in the suburban neighborhoods and do not go through the cycles that typically the white, Hispanic and African Americans have gone through. A little less than 60% of the respondents were employed for wages. This might reflect a higher number of stay at home parents and the higher average age of the respondents (57 years). Table 44 presents the descriptive statistics for the variables used in the analyses of this neighborhood type. Again, these are the same variables used in the urban and higher density suburban analyses.

Table 44: LDS Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Std. Dev.
VehYou	318	0	4	1.35	0.64
VehAll	276	0	9	2.22	0.95
VehYear	323	1988	2008	2003.91	3.67
VehCyl	303	4	8	5.81	1.27
VehMiles	319	200	200000	42590.57	39295.87
Age	317	18	92	57.04	15.03
Educ	324	10	19	16.75	2.52
Num_Child	314	0	4	0.65	1.01
Inc_Supports	309	0	10	2.73	1.44
PIncome	278	5000	155000	73417.27	49971.24
HIncome	273	5000	155000	108516.48	44853.69
Pct_WorkTrips_W	196	0.00	100.00	5.53	18.65
Pct_WorkTrips_T	196	0.00	16.67	0.09	1.19
Pct_WorkTrips_D	196	0.00	100.00	94.38	18.67
Pct_OptTrips_W	323	0.00	87.50	6.83	15.39
Pct_OptTrips_T	323	0.00	27.27	0.18	1.85
Pct_OptTrips_D	323	12.50	100.00	92.99	15.45
Pct_AllTrips_W	325	0.00	83.12	6.92	14.84
Pct_AllTrips_T	325	0.00	27.27	0.20	1.89
Pct_AllTrips_D	325	16.88	100.00	92.88	14.92
Ann_WorkMiles_W	196	0.00	7072.00	88.59	553.07
Ann_WorkMiles_T	196	0.00	572.00	2.92	40.86
Ann_WorkMiles_D	196	0.00	69940.00	3354.82	6112.06
Ann_OptMiles_W	324	0.00	2802.80	68.11	283.20
Ann_OptMiles_T	324	0.00	577.20	2.28	32.66
Ann_OptMiles_D	324	0.00	18153.20	1921.06	1972.68
Ann_AllMiles_W	325	0.00	7072.00	121.32	511.75
Ann_AllMiles_T	325	0.00	577.20	4.03	45.41
Ann_AllMiles_D	325	0.00	72867.60	3938.36	5406.37
Ann_Fuel_Consump	286	0.00	4857.84	212.92	353.03
Ann_CO_Emissions	287	0.00	181686.96	16300.46	18430.98

* Ann_Fuel_Consump and Ann_CO_Emissions show annual total environmental burdens for travel to end-point destinations.

Cluster Analyses: The Low Density Suburban Neighborhood Typology

Starting with the Cluster Analyses on demographic variables, the results revealed groupings based on: 1) race; 2) number of dependents in the household; 3) employment (for wages) and employment in the professional occupation categories; and 4) the number of vehicles owned (*see Table 45*). The second of the last set of analyses, on all variables, revealed groups that differed on: 1) work and non-work trips undertaken by walking and driving; 2) fuel consumption and emissions generated; 3) vehicles owned; and 4) the year of and miles on the vehicles used for travel purposes (*see Table 46*). For each of the two Cluster analyses, first the clusters with low membership numbers (<4) are discussed, followed by the discussion of the clusters with sufficient membership numbers (>=4).

Table 45: Cluster Analysis on Demographic and Socio-economic Variables – LDS

CL	Dependants		Employment		Veh_Age		Race		Veh_Ownership	
	Inc_Sup	Child	D_Emp	D_Prof	Year	Miles	Wh	Bl	You	All
1	4.4	1.8	0.8	0.7	2006	27901	0.9	0	1.1	2.4
2	2.8	0.5	0	0	2000	79850	0.9	0	1.8	2.4
3	3.1	0.7	1	0.9	2000	94568	1	0	1.3	2.3
4	3	0.4	0.9	0.8	2006	26659	1	0	2.5	3.2
5	2	0.1	0.6	0.5	2006	20583	1	0	1.2	1.7
6	1	0	0.3	0.3	2007	7667	0	0.7	1	1.7
7	5	1.7	0.7	0.6	2004	61957	0	0.9	1	2.9
8	6	1	1	1	2007	800	1	0	3	9

Table 46: Cluster Analysis on All Variables – LDS

CL	Energy Use		Work Trips		Non-Work Trips		Employment	
	Fuel	CO	%Trps_W	%Trps_D	%Trp_W	%Trp_D	D_Empl	D_Prof
1	4.8	9.2	5.1	94.9	1.9	98.1	0.7	0.6
2	4.9	9.3	3.1	96.9	34.5	65.5	0.8	0.8
3	3.7	8.1	100	0	21.4	78.6	0.5	0.5
4	5.6	9.9	2.1	97.7	1.4	98.6	0.9	0.9
5	5.6	10.1	11.9	88	2.1	97.9	1	0.9
6	5.1	9.4	0	100	1.8	98.2	0.7	0.6

Table 46 (Contd.)

CL	Dependants		Veh_Age		Race		Veh_Ownership		Walk (Mode)	
	Inc_Sup	Child	V_Year	V_Miles	Wh	Bl	You	All	AllMiles	WrkMiles
1	3.9	0.6	2005	36497	0.9	0	2.7	3.3	1.2	0.9
2	3.3	1.1	2004	44392	1	0	1.4	2.2	5.2	0.5
3	3.5	1	2007	17050	1	0	1	1.5	0	0
4	3.1	0.9	2006	24716	0.9	0	1.1	2.1	0.7	0.5
5	3.2	0.8	2000	98638	0.9	0	1.2	2.5	1.8	1.4
6	4	1.3	2005	47557	0	0.7	1	2.7	0.6	0

The 8 group K-Means Cluster analysis on the demographic variables yielded two clusters that had less than 4 members. Results are discussed below:

- <u>Cluster 6</u> is a group of 3 members, all with a low number of dependents and no children living at home. The unique part is that this group has 2 African American members and 1 member of another race, and they have the newest cars with the lowest mileage on them. Two of the three respondents in this group are also not employed for wages.
- <u>Cluster 8</u> identified one member who is a white respondent that is employed as a professional, and has a high number of dependents. The uniqueness comes from the fact that this respondent has a large number of cars accessible to the respondent and the household (3 for the respondent and 9 for all members of the household). The respondent also has a new car (2 years old) with very low miles on it.
- Amongst the other clusters, <u>Cluster 1</u> has an all-white membership of respondents who have a relatively high number of dependents (4.4) and children living at home (1.8). They have newer cars (3 year old) with relatively low miles on them.
- <u>Cluster 2</u> identified a group of almost all white respondents who do not work for wages.
- <u>Cluster 3</u> identified a group of all white respondents, who are employed as professionals, and who have vehicles that are older (9 years old) with most miles on them (almost 95,000 miles on average).
- <u>Cluster 4</u> is composed of white respondents that are mostly employed as professionals. They have newer cars (3 years old) and a higher number of cars accessible to them (about 2.5 cars on an average).

- Cluster 5 has a low number of dependents and almost no children under 18 years living at home. Relatively few of these respondents are employed for wages, yet they have newer cars with low miles on them.
- Cluster 7 identified a group of mainly African American respondents, most of who are employed for wages. This group also has a high number of dependents (5) and children under the age of 18 living at home (1.7).

The 6 group Cluster analysis on all variables identified only one group with less than 4 members.

- Cluster 3 identified 2 members who are white, have relatively new cars, but the unique attribute of this group is that they walk to all their work based trips, however, the annual mileage for walking to work based trips is 0. This might suggest that they have home based businesses or live in the same structure as their business is in.
- Cluster 1 identified an almost all white group of respondents that have a high number of dependents, and also a high number of cars for themselves and their household. Most of their trips for all purposes are by driving, and they have average aged cars that are 4 years old with relatively low miles on them.
- Cluster 2 identified a group of white respondents who walk to 1/3 of their non-work trips, the highest average percentage for this neighborhood type.
- Cluster 4 identified a group of white respondents who have high levels of energy use. They consume the most fuel and are responsible for the highest levels of pollutant emissions, the carbon monoxide emissions. As would be expected, they drive to most to their destinations.

- Cluster 5 consists of a group of white respondents who have the oldest cars (9 years old) and have the highest miles on their vehicles. They walk to work about 12% of the time, and usually drive for non-work trips. Due to their older cars, they are also high energy users. They are responsible for relatively higher fuel consumption levels and carbon monoxide emissions.
- Cluster 6 is a group of mostly African American respondents who have a high number of dependents (4) and children living at home (1.3), the highest numbers for this neighborhood type. This group drives to almost all of their destinations, be it for work purposes or for non-work purposes.

Regression Analyses: The Low Density Suburban Neighborhood Typology

In order to test the hypotheses, the next set of analyses are the Regression Analyses. The Regression Analyses are again broken down into the assessment of 'work based trips', 'non-work based trips' and 'all trips'. The results show the following outcomes:

- **For work based trips** (*see tables 47 and 48*):
    - The analysis on the percentage of travel undertaken by walking as the mode did not show any linear relationships with socio-economic characteristics [Hypothesis C]
    - The analysis on the percentage of travel undertaken by public transit as the mode did not show any linear relationships with socio-economic characteristics [Hypothesis B]

    - The analysis on the percentage of travel undertaken by <u>driving</u> as the mode did not turn out significant [Hypothesis A]
    - The analysis on the total annual miles for trips undertaken by <u>walking</u> did not show linear relationships with socio-economic characteristics [Hypothesis F]
    - The analysis on the total annual miles for trips undertaken by <u>public transit</u> did not show linear relationships with socio-economic characteristics [Hypothesis E]
    - The total annual miles for trips undertaken by <u>driving</u> had a significant and positive association with whether the respondent was *employed (for wages)* and *household income* [Hypothesis D]
- **<u>For the non-work trips</u>** (*see tables 47 and 48*):
    - The analysis on the percentage of travel undertaken by <u>walking</u> as the mode did not show linear relationships with socio-economic characteristics [Hypothesis C]
    - The analysis on the percentage of travel undertaken by <u>public transit</u> as the mode had a negative association with being *black* and being *white* and had a positive association with the *age* of the respondent [Hypothesis B]. Caution would need to be raised here as even though the regression is significant on the whole, there were only a handful of respondents who stated that they travel by public transit and as such, this result is unrealistic.
    - The analysis on the percentage of travel undertaken by <u>driving</u> as the mode did not show linear relationships with socio-economic characteristics [Hypothesis A]
    - The analysis on the total annual miles for trips undertaken by <u>walking</u> did not show linear relationships with socio-economic characteristics [Hypothesis F]

- The analysis on the total annual miles for trips undertaken by public transit had a negative association with being *black* and being *white* and had a positive association with the *age* of the respondent [Hypothesis E]. Again, there were only a few respondents that said they travel by public transit and so this result should be read with caution.
- The total annual miles for trips undertaken by driving had a significant and negative association with whether the respondent was *employed (for wages)* and the number of *children* (under 18 years) living at home [Hypothesis D]

- **For all trips** (*see tables 47 and 48*):
  - The analysis on the percentage of travel undertaken by walking as the mode did not show linear relationships with socio-economic characteristics [Hypothesis C]
  - The analysis on the percentage of travel undertaken by public transit as the mode had a negative association with being *black* and *white*, and a positive association with the *age* of the respondent [Hypothesis B]. As mentioned earlier, caution would need to be raised here as even though the regression is significant on the whole, there were only a handful of respondents who stated that they travel by public transit and as such, this result needs to be viewed with caution.
  - The analysis on the percentage of travel undertaken by driving as the mode showed no linear relationships with socio-economic characteristics [Hypothesis A]
  - The analysis on the total annual miles for trips undertaken by walking did not show linear relationships with socio-economic characteristics [Hypothesis F]

- The analysis on the total annual miles for trips undertaken by <u>public transit</u> did not show linear relationships with socio-economic characteristics [Hypothesis E]
- The total annual miles for trips undertaken by <u>driving</u> had a significant and positive association with household *income* and whether the respondent was *employed (for wages)* and a negative association with the *age* of the respondent [Hypothesis D]

Table 47: LDS Regression results - Mode

Variable	Driving Trips			Transit Trips			Walking Trips		
	Work	Non-Work	All	Work	Non-Work	All	Work	Non-Work	All
Constant	106.531	**83.255***	**87.551***	-0.785	1.184	0.797	-5.746	15.561	11.653
# Dependant Children	1.123	2.146	2.325	-0.153	0.043	-0.043	-0.970	-2.189	-2.281
Dummy_Black	0.852	5.299	4.673	-0.055	**-1.570**	**-1.470**	-0.798	-3.729	-3.203
Dummy_White	-6.061	-1.795	-2.886	0.022	**-1.785***	**-1.676***	6.039	3.581	4.563
Education	-0.778	-0.361	-0.548	0.031	-0.044	-0.028	0.747	0.405	0.576
Dummy_Employed	-0.869	-0.636	0.276	0.042	-0.018	-0.009	0.827	0.654	-0.267
Hshld_Income	0.025	**0.025***	0.022	0.001	0.001	0.001	-0.026	**-0.026***	**-0.023***
Age	-0.054	**0.155***	**0.152***	0.001	**0.019**	**0.018***	0.053	**-0.174**	**-0.170**
R^2	.028	.030	.035	.013	.078	.066	.027	.0335	.041
Adj. R^2	-.016	.002	.007	-.032	.051	.039	-.017	.007	.013
N	163	248	250	163	248	250	163	248	250

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

Table 48: LDS Regression results – Annual Miles

Variable	Driving Miles			Transit Miles			Walking Miles		
	Work	Non-Work	All	Work	Non-Work	All	Work	Non-Work	All
Constant	**3.754***	**6.705*** ***	**7.078*** ***	-0.299	0.233	0.055	-1.772	2.095	0.778
# Dependant Children	-0.170	**-0.243** **	-0.161	-0.058	-0.004	-0.046	0.081	-0.001	-0.025
Dummy_Black	1.485	-0.377	0.172	-0.021	**-0.340** **	-0.349	-0.123	0.054	-0.044
Dummy_White	-0.020	0.067	-0.035	0.008	**-0.397** ***	**-0.393** ***	0.464	**1.009** *	**1.198** **
Education	0.016	0.049	0.039	0.012	-0.008	3.056E-5	0.028	0.009	0.051
Dummy_Employed	**1.314***	**-0.341** **	**0.453** ***	0.016	-0.014	0.020	0.539	-0.191	0.274
Hshld_Income	**0.009** **	0.001	**0.003** **	0.000	0.000	0.000	0.001	-0.002	-0.001
Age	-0.031	-0.010	**-0.016** **	0.000	**0.004** *	0.004	0.012	**-0.028** **	**-0.023** *
R^2	.119	.056	.159	.013	.077	.037	.028	.039	.044
Adj. R^2	.079	.028	.135	-.032	.051	.010	-.016	.011	.016
N	163	249	250	163	249	250	163	249	250

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

Table 49: LDS Regression results – Vehicle Characteristics

	Vehicle			Annual Environmental Burdens	
	Veh-All	Veh_Year	Veh_Cyl	Fuel Consumption	CO Emissions
Constant	1.069	**2002.450*** **	**5.588*** **	**4.253*** **	**8.803*** **
# Dependant Children	0.067	0.297	0.013	-0.019	-0.038
Dummy_Black	0.236	0.167	-0.130	0.143	-0.200
Dummy_White	0.121	-1.423	-0.463	**-0.554** **	-0.455
Education	-0.003	-0.127	-0.058	0.013	0.017
Dummy_Employed	0.118	-0.148	-0.157	**0.562*** **	**0.590*** **
Hshld_Income	**0.004*** **	**0.011*** **	**0.003** **	**0.004*** **	**0.003*** **
Age	-0.004	0.027	0.013	**-0.010** **	**-0.014** **
R^2	.109	.056	.048	.255	.216
Adj. R^2	.079	.025	.014	.230	.190
N	215	246	232	219	220

Note: * p < 0.1; ** p < 0.05; *** p < 0.01; Values reported are coefficients; Significant coefficients are in bold. Shaded columns represent the regressions that did not result in a good model fit.

- The number of vehicles owned by the household had a significant and positive association with *household income* (*see table 49*) [Hypothesis H]
- For those respondents that have access to and use a private vehicle for any part of their travel activity, the analysis on the year of the vehicle used for travel did not show linear relationships with socio-economic characteristics (*see table 49*) [Hypothesis G]
- For those respondents that have access to and use a private vehicle for any part of their travel activity, the analysis on the engine size of the vehicle used for travel did not show linear relationships with socio-economic characteristics (*see table 49*) [Hypothesis I]
- For those respondents that have access to and use a private vehicle for any part of their travel activity, the annual fuel consumption was significantly and positively associated with *household income* and whether the respondents were *employed (for wages)* and negatively associated with the *age* of the respondent and whether the respondent was *white* (*see table 49*) [Hypothesis D]
- For those respondents that have access to and use a private vehicle for any part of their travel activity, the annual carbon monoxide emissions was significantly and positively associated with whether the respondents were *employed (for wages),* the *household income,* and negatively associated with the *age* of the respondent and the number of *children* under the age of 18 years living at home (*see table 49*) [Hypothesis D]

The regression analyses show that many of the results on travel mode and annual miles for different trip purposes came out as insignificant. The results suggest that employment for wages had a positive association with the annual miles of car travel, as did the household income. This can be understood as the socio economic characteristics of the residents in this neighborhood would not significantly shape the variation in travel patterns of the residents using other modes of travel. Given the existing literature on urban form and travel patterns, this can be expected due to the extreme built environment characteristics of these neighborhoods—low density, single use zoned, and disconnected neighborhoods—which are built as highly isolated residential pods, generally forcing everyone to drive in these neighborhoods, a travel behavior outcome that likely generated the insignificant results. The highly skewed data on mode travel is also reflective of this. The transit mode travel regressions that did turn out significant should be ideally considered insignificant because there were only a handful of respondents (at the most) who used transit for any part of their travel needs. The same would be the case for some of the other significant regressions such as the annual miles to non-work and all destinations combined by driving. Even though these results were significant, the dependent variables mentioned above have a skewed distribution and therefore the results would be biased. On the other hand, the environmental burdens did turn out significant and those had a class dimension. So even though there was not a significant variation in the travel patterns that socio-economic characteristics were facilitating, there was a significant impact of the socio-economic characteristics on the environmental burdens (i.e. fuel consumption and pollutant emissions) and this would be the case primarily due to the type of vehicle that the respondents in different income categories owned. A more nuanced assessment of this variation can be teased out in the following qualitative analysis.

A Discussion by Income Groupings: The Low Density Suburban Neighborhood Typology

In order to further understand the different characteristics and behavior of respondents, the respondents were divided into three income groups (low, medium, and high). This income based structure for the lower density suburban neighborhood typology is as follows.

Table 50: LDS Respondents split into three Household Income groups

Household Income	*Count*	*Percentage*
$5,000 to $50,000	38	14%
>$50,000 to $100,000	74	27%
>$100,000 to $155,000	161	59%
Total	273	100%

The concentration of the wealth in the lower density suburban neighborhoods becomes evident in table 50. Over half of the respondents (59%) fall into the highest one-third of the household income range, while only 14% belong to the lowest one-third of the household income range. The average household income for the entire neighborhood type was $108,164. This was the highest average income among the three neighborhood groupings (HDU, HDS, and LDS).

Table 51: LDS Vehicle Characteristics

	Income Range		
	Low	Middle	Upper
Vehicles for you	1.2	1.4	1.4
Vehicles for all in household	1.7	2.0	2.4
Vehicle Year	2003	2004	2004

Table 52: LDS Demographic Characteristics

	Income Range		
	Low	Middle	Upper
Age	66.9	57.5	52.9
Education	15.1	16.6	17.3
Number of people the Income Supports	1.7	2.4	3.2
Number of children living at home	0.2	0.6	0.9

The range in vehicle characteristics among the three income groupings, see table 51, shows an expected trend. The higher the income, the greater the number of cars in the household and the newer the cars. The range of vehicle characteristics (such as the number of vehicles and age of the vehicle) between the low income group and the upper income group is not much though, so most of the people in this neighborhood type, regardless of income, have similar vehicle characteristics. The demographic table, on the other hand shows a significant range in the age of the respondent. The low income groups are much older than the upper income groups. This could be expected as the older respondents would start entering retirement and their incomes would be lower. The education and number of dependents in the house also depicts an expected trend. The older group consists largely of empty nesters and their income needs to support fewer people.

Table 53: LDS Mode of Travel Based on Usual Weekly Travel Patterns

	Income Range		
	Low	Middle	Upper
% WorkTrips by Walk	5.8	6.7	5.9
% WorkTrips by Transit	0	0	0.1
% WorkTrips by Drive	94.2	93.3	94
% Non-Work Trips by Walk	9.6	6.8	6.1
% Non-Work Trips by Transit	0	0.4	0.1
% Non-Work Trips by Drive	90.4	92.8	93.8
% All Trips by Walk	9.0	6.8	6.5
% All Trips by Transit	0	0.4	0.2
% All Trips by Drive	91.0	92.8	93.4

Table 54: LDS Average Annual Miles to End-Point Destinations by Trip Purpose Based on Usual Weekly Travel Patterns

	Income Range		
	Low	Middle	Upper
Annual Miles for WorkTrips by Walk	0.0	44.0	133.4
Annual Miles for WorkTrips by Transit	0.0	0.0	5.0
Annual Miles for WorkTrips by Drive	1295.3	2386.9	4158.7
Annual Miles for Non-Work Trips by Walk	21.4	119.0	46.4
Annual Miles for Non-Work Trips by Transit	0	8.1	0.5
Annual Miles for Non-Work Trips by Drive	1796.2	1935.9	2012.9
Annual Miles for All Trips by Walk	21.4	147.3	140.9
Annual Miles for All Trips by Transit	0.0	8.0	4.0
Annual Miles for All Trips by Drive	2156.0	3533.5	4957.6

The mode of travel table, table 53, shows a more or less homogenous travel behavior by the respondents of all three income groups. As mentioned before, public transit is not used on a regular basis as it is not widely available in these neighborhoods. Walking is used sparingly, only for non-work trips. Respondents in the lowest income grouping walk for about 9% of their non-work trips, while respondents in the upper income grouping walk for about 6% of their non-work trips. Most of the travel in the lower density suburban neighborhood typology, regardless of income, is by car.

The annual miles table, table 54, shows greater diversity. The public transit mileage is quite similar and very low. However, the annual miles traveled by driving, shows a clear distinction by class. Respondents in the upper income grouping travel farther distances by car for all trip purposes. The greatest variance is for work trips, where the upper income group travels over 3.2 times the total distance that the lower income grouping travels. For non-work trips, the upper income group travels a distance that is 1.1 times greater than the total distance that the lower income grouping travels. For all trips combined, the upper income group traveled 2.3 times the total annual distance to end-point locations in comparison to the lower income grouping. The middle income group has values that fall in the middle of the range that the upper and lower income groups have.

Table 55: LDS Average Environmental Burdens Based on Usual Weekly Travel Patterns

	Income Range		
	Low	Middle	Upper
Annual Fuel Consumption	194.2	339.0	580.6
Annual Carbon Monoxide Emissions	16306.0	29506.6	41698.6

*The environmental burdens calculations are a result of both end- and return-destination trips.

The table on environmental burdens shows, once again, a familiar and expected outcome. The upper income sub-group consumes about 3 times the annual fuel (in gallons) in comparison to the lower income sub-group. The pollutant emissions show similar trends, with the respondents in the upper income grouping emitting about 2.6 times the annual carbon monoxide levels (in grams) when compared to respondents in the lower income grouping, while the middle income group has values that fall in between the upper and lower income sub-groups. Apart from the variance in the travel behavior, the higher pollutant emissions among the wealthier could be attributed to the upper income group having more powerful engines and larger vehicles than the lower income group. These vehicle characteristics would lead to the higher amounts of fuel required by the vehicles and higher amounts of emissions generated by these vehicles.

Discussion

The results of the analyses on the LDS neighborhood type showed clusters that mainly differed on the number of vehicles, age of the vehicles, miles on the vehicles, annual miles to all trips by driving, the number of dependents, and age. These clusters indicated that the groups were formed more on the different socio-economic characteristics than on the travel patterns. This facet was expected. We know these neighborhoods—due to the characteristics of their built environment—encourage travel by private vehicle and it was no surprise to see this scale of automobile dependence. The regressions, even though most on travel behavior were insignificant, are telling of this facet. These are low density, largely single use zoned, and disconnected neighborhoods, where everyone drives.

The most of the regressions on the mode of travel and the annual miles traveled for different purposes were insignificant. The annual miles traveled for all purposes by driving resulted in household income, employment (for wages) and the age of the respondent as the characteristics that significantly affected this type of travel. So what this insignificance tells us is that after holding the built environment constant, there was no significant relationship with the various socio-economic characteristics and variation in travel behavior. Two things are worth noting at this point. First, there is not that much of a range in the socio economic characteristics themselves, and second, there was not much of a difference in travel behavior. Knowing that the latter is true for these neighborhoods, the regressions show that travel patterns for the residents in these neighborhoods is heavily dependent on using a private vehicle. The insignificant mode choice regressions imply this. The annual miles regressions, however, did imply that socio economic characteristics—like income and employment—have a positive effect, and the age of the resident has a negative effect on the annual miles for <u>all</u> trips that will be traveled by driving.

The breakdown by income sub-groups supports the regression results. It is evident that the upper income grouping of residents drove more than three times the annual distance to work than the lower income grouping of residents. For non-work purposes, the lower income range residents walked the most percentage of trips, compared to the other two income groups, but they did so for the least total miles. The middle income group walked the greatest distance for these trip purposes. Combining all the trips, the upper income grouping drove three times the distance annually when compared to the distances that the lower income grouping drove, and that fact was translated into much greater environmental burdens. Respondents in the upper income grouping were responsible for about three times the fuel consumption and 2.6 times the carbon monoxide pollutant emissions than the respondents in the lower income range grouping.

Commentary

The purpose of this research, and the specific focus of the intra-neighborhood analysis, was to control for the built environment and tease out the relationships between socioeconomic characteristics and travel behavior, along with the associated environmental burdens, the annual gasoline consumption and the annual carbon monoxide emissions. Across all three neighborhoods, the main finding was that class had a significant relationship with travel patterns and environmental burdens, both gasoline consumption and vehicle emissions. Even while living in the same neighborhood, people with different socio economic characteristics behaved differently. The wealthier traveled more times and longer distances with their private vehicles than did the lower income residents and consequently, they were responsible for higher environmental burdens. A summary of the travel behavior and environmental burdens by income group for the three neighborhood typologies is presented in table 56.

The Cluster Analyses on each neighborhood type showed that the suburban neighborhoods, both HDS and LDS, had larger variations (resulting in clusters) in travel patterns than in the socio-economic characteristics of the residents. The variations in socio-economic characteristics were more prevalent in the urban neighborhoods (HDU) and the higher density suburban (HDS) neighborhoods, with the HDS neighborhoods showing a greater variation in socio-economic characteristics than the HDU neighborhoods. Variations in travel patterns were greater for the HDS neighborhoods than the LDS neighborhoods.

Table 56: Summary of Travel Behavior by Income Group and Neighborhood Typology

	Higher Density Urban			
	Low Income	*Middle Income*	*Higher Income*	***All***
Mode Choice (Average per Respondent)				
% Work Trips by Walk	16	12.6	0	**13.5**
% Work Trips by Transit	16.5	7.7	0.5	**13.5**
% Work Trips by Drive	67.6	79.7	99.5	**73.0**
% Non-Work Trips by Walk	27.4	12.2	12.2	**23.6**
% Non-Work Trips by Transit	9.2	3.1	6.9	**8.3**
% Non-Work Trips by Drive	63.4	84.7	80.9	**68.1**
% All Trips by Walk	26.8	13.7	6.8	**23.0**
% All Trips by Transit	10.7	4.4	7.1	**9.8**
% All Trips by Drive	62.5	81.9	86.1	**67.2**
Average Annual Distances (Average Miles per Respondent to end-point destinations)				
Work Trips by Walk	157.7	821.0	0.0	**287.2**
Work Trips by Transit	238.5	644.1	0.0	**299.3**
Work Trips by Drive	1209.3	3172.4	4809.1	**1849.7**
Non-Work Trips by Walk	199.1	522.6	213.5	**224.4**
Non-Work Trips by Transit	214.2	615.7	219.0	**259.7**
Non-Work Trips by Drive	1036.6	2590.3	2179.6	**1214.6**
All Trips by Walk	259.8	1097.3	213.5	**41.1**
All Trips by Transit	305.9	1066.5	219.0	**381.0**
All Trips by Drive	1501.7	4811.0	5385.6	**1969.7**
Fuel Consumption (gallons)	221	485	589	**99.6**
CO Emissions (grams)	20141	38212	51465	**8674.0**
Avg. Fleet Fuel Economy (miles per gallon)	21.7	20.5	20.4	**21.3**
Avg. Fleet CO Emissions (grams per mile)	4.3	4.4	4.4	**4.3**

Table 56 (Contd.)

	Higher Density Suburban			
	Low Income	*Middle Income*	*Higher Income*	***All***
Mode Choice (Average per Respondent)				
% Work Trips by Walk	28.9	13.2	14.9	**16.0**
% Work Trips by Transit	21.2	5.8	3.5	**6.7**
% Work Trips by Drive	50.0	81.1	81.6	**77.3**
% Non-Work Trips by Walk	32.1	20.0	19.0	**21.5**
% Non-Work Trips by Transit	3.7	0.4	0.6	**1.1**
% Non-Work Trips by Drive	64.2	79.6	80.4	**77.4**
% All Trips by Walk	29.3	19.0	18.1	**20.1**
% All Trips by Transit	8.4	2.0	1.6	**2.8**
% All Trips by Drive	62.3	79.1	80.3	**77.1**
Average Annual Distances (Average Miles per Respondent to end-point destinations)				
Work Trips by Walk	74.9	47.1	228.4	**130.7**
Work Trips by Transit	126.0	35.2	77.5	**64.2**
Work Trips by Drive	478.9	1963.6	2198.7	**1927.0**
Non-Work Trips by Walk	146.3	101.7	67.8	**99.9**
Non-Work Trips by Transit	30.5	6.6	3.6	**9.1**
Non-Work Trips by Drive	789.2	858.1	896.7	**855.6**
All Trips by Walk	189.4	136.3	233.1	**188.0**
All Trips by Transit	103.1	32.4	59.9	**52.5**
All Trips by Drive	1064.9	2300.4	2484.8	**2156.1**
Average Annual Environmental Burdens (Average per Respondent)				
Fuel Consumption (gallons)	115	216	262	**106.3**
CO Emissions (grams)	9653	19059	21172	**8870.3**
Avg. Fleet Fuel Economy (miles per gallon)	23	21.8	20.7	**21.6**
Avg. Fleet CO Emissions (grams per mile)	4.0	4.2	4.1	**4.1**

Table 56 (Contd.)

	Higher Density Suburban			
	Low Income	*Middle Income*	*Higher Income*	***All***
Mode Choice (Average per Respondent)				
% Work Trips by Walk	5.8	6.7	5.9	**5.5**
% Work Trips by Transit	0	0	0.1	**0.1**
% Work Trips by Drive	94.2	93.3	94	**94.4**
% Non-Work Trips by Walk	9.6	6.8	6.1	**6.8**
% Non-Work Trips by Transit	0	0.4	0.1	**0.2**
% Non-Work Trips by Drive	90.4	92.8	93.8	**93.0**
% All Trips by Walk	9.0	6.8	6.5	**6.9**
% All Trips by Transit	0	0.4	0.2	**0.2**
% All Trips by Drive	91.0	92.8	93.4	**92.9**
Average Annual Distances (Average Miles per Respondent to end-point destinations)				
Work Trips by Walk	0.0	44.0	133.4	**88.6**
Work Trips by Transit	0.0	0.0	5.0	**2.9**
Work Trips by Drive	1295.3	2386.9	4158.7	**3354.8**
Non-Work Trips by Walk	21.4	119.0	46.4	**68.1**
Non-Work Trips by Transit	0	8.1	0.5	**2.3**
Non-Work Trips by Drive	1796.2	1935.9	2012.9	**1921.1**
All Trips by Walk	21.4	147.3	140.9	**121.3**
All Trips by Transit	0.0	8.0	4.0	**4.0**
All Trips by Drive	2156.0	3533.5	4957.6	**3938.4**
Average Annual Environmental Burdens (Average per Respondent)				
Fuel Consumption (gallons)	194	339	581	**212.9**
CO Emissions (grams)	16306	29507	41699	**16300.5**
Avg. Fleet Fuel Economy (miles per gallon)	21.0	20.7	19.2	**20.1**
Avg. Fleet CO Emissions (grams per mile)	4.0	4.3	4.2	**4.2**

The regression analyses showed that after holding the built environment constant, socio-economic characteristics had significant relationships with travel behavior and environmental burdens, especially when it came to non-work trips and all trips combined. Age, as a socio-demographic variable came out as significant in many of the regressions affecting travel by walking and some by public transit. It is reasonable to expect that age is a characteristic that would shape mode of travel. Older residents prefer to travel by car than to travel by public transit or walking to their various destinations.

Household income, education, and employment status (whether the respondent was employed for wages) consistently came out as significant for travel associated with public transit and driving. In general, the more educated the respondents are, those with higher household incomes and the greater the chance that the respondent was employed for wages, the greater the propensity to drive to destinations compared to those with lower values for those similar socio-economic characteristics. This is precisely what was hypothesized: that those with higher socio-economic characteristics drive more often and longer distances. These residents are also, consequently, responsible for higher levels of environmental burdens. The regressions within each neighborhood built environment typology allow the analysis to focus on the socio-economic composition of the population and their impacts on travel. One important dimension to travel captured in this analysis was that the variation in travel behavior by residents in the same neighborhood was significant for mainly those neighborhood typologies that had higher densities, mixed land uses, and higher connectivity (the HDU and the HDS neighborhoods). In the LDS neighborhoods, the built environment was developed to facilitate automobile travel and therefore only the regressions on travel behavior for all trips combined and the environmental burdens came out as significant. This too is an important recognition in the outcomes. If the neighborhood typology itself has no options for alternative travel modes and destinations, then it forces everyone living in such environments to use their automobiles for any and all travel purposes (except walking for leisure). Another important issue that needed recognition was that many of the mode travel variables were skewed and so the regression results would be biased. Therefore it is important to understand that the analyses results would be sensitive to this. At the same time, since the regressions are not used for prediction, rather just to indicate relationships, it is safe to use the results, albeit with caution. The main point however, is that the environmental burdens variables and regressions were significant and can be stated with confidence.

The breakdown of the neighborhood types into income subgroups, based on tertiles, provided added texture to the study of the socio-economic impacts of travel and the resulting environmental burdens. These impacts are discussed by travel purpose below:

Work-based Trips

Looking at *mode of travel*, in the urban (HDU) and the higher density suburban (HDS) neighborhoods, the upper income range residents used their vehicles about 1.5 times more than the lower income residents did for work purposes. In the lower density suburban (LDS) neighborhoods, there was no difference between the income groups' usage of vehicles as their preferred mode of travel for work purposes. Due to the characteristics in urban form, virtually everyone needed to drive to work.

The difference in the *distance traveled* between the higher and lower income groups in all neighborhood typologies was significant. In the HDU neighborhoods, on average, the higher income grouping residents traveled about three times the annual distance to work than the lower income grouping residents. In the HDS neighborhoods, the higher income range residents traveled over 3.7 times the average annual distance to work when compared to the lower income range residents. In the LDS neighborhoods, the higher income range residents traveled over 3.3 times the average total annual distance to work when compared to the lower income range residents. In the case of all three neighborhood typologies, the higher income groupings had jobs that were further away from their home when compared to the lower income groupings.

In case of the HDU neighborhoods, the higher end jobs are located in the suburbs and the higher income residents—at least in the context of Detroit income averages—from the Detroit neighborhoods are required/need to travel great distances to get to their place of employment (Darden and Kamel, 2000; Darden and Thomas, 2013). At the same time, data from the survey shows that these higher income residents will not necessarily sell their current homes in the inner city and move closer to their jobs. This, in fact, can be expected for all neighborhoods, since people switch jobs on shorter time intervals than they are necessarily willing to—or can afford to—move from their neighborhood. On a regional scale, in the case of metropolitan areas, travel to work are the high pressure commutes where people have to travel longer distances to get to work opportunities, in large part because people will change jobs but will unlikely relocate every time they get a new job.

For the HDS neighborhoods, the burden of travel for work purposes is the lowest. So while the study shows in general that the upper income residents travel further for work purposes than the lower income residents, it also shows that the upper income groupings in the HDU and

LDS neighborhoods travel 1.7 and 1.9 times the annual distance that the upper income grouping travels to work in the HDS neighborhoods. This is reflective of both the built environment characteristics and the fact that the higher paying jobs have moved out into, or in close proximity, to these HDS areas, where along with employment opportunities, the quality of life is also high and desired by many upper income residents. Many Ann Arbor residents, for instance, have jobs in relative close proximity due to the rich and robust characteristics of this activity node. In contrast, in the Detroit lower eastside neighborhoods, despite the high densities, mixed land uses, and high connectivity, there are simply not these types of employment opportunities. In part, the extreme disinvestment and decline within Detroit has shaped these outcomes.

For the LDS neighborhoods, it is recognized from the built environment objective data that these are large homes on large lots in isolated residential neighborhood pods. From the Census data and from the neighborhood surveys, it is also evident that these are expensive homes in upper income neighborhoods. The residents of these neighborhoods are generally higher income earners that are willing to drive long distances to work, as evident in time and distance, in order to attain the particular quality of life desired, living in isolated and secluded neighborhoods with large homes on large lots.

Non-Work Trips

For non-work trip purposes, we start seeing the residents make use of other *travel modes*, particularly walking. As is expected, the lower income range residents walk and take transit (where available) more than the middle and upper income range residents. The HDU neighborhood residents face a situation where they have only a few good choices when it comes to shopping and service availability. Shopping for food is a necessity, however, the residents in the urban neighborhoods have to travel further to get to supermarkets that are located away from the city, and particularly in the surrounding suburbs. As these neighborhoods experience disinvestment and decline, basic daily destinations are unavailable within these neighborhoods—whether national supermarket chains or personal services—and the residents have to travel further distances due to a lack of opportunities and choices. Hence, these neighborhoods maintain lower accessibility levels to many necessary daily destinations, despite the higher densities, the high connectivity, and the mixed land uses.

In the HDS neighborhoods though, for travel that is less constrained by time and location (non-work trips), people tend to vary their mode of travel and make greater use of walking and public transit. This lends support, again, to the notion that within these robust communities, there are ample choices for destinations of different purposes and this gives the residents the choice to use alternative forms of travel to the car. The increase in walking as a mode of transportation for non-work purposes is the least in the LDS neighborhoods and this was expected since these neighborhoods rarely have any destinations close by that would be accessible by walking (unless residents go for leisurely walks in their neighborhood).

Across all regressions in the three neighborhood types, socio economic characteristics had a significant relationship with the different modes of travel (and especially walking) and the miles traveled. All three income groups in all neighborhoods walked more times to non-work destinations than to work destinations, however, the lower income groups walked to all destinations the most.

As for transit, the lack of an extensive transit system in the suburbs leads to a lower use of this mode of transportation. The prevalence of transit use is highest in the HDU neighborhoods, and the use of transit was higher for work purposes by the lower and middle income group residents than for non-work trip purposes. Only the higher income range residents increased their usage of transit from work trips to non-work trips, that too only marginally. Even so, the lower income grouping in the HDU neighborhoods used transit the most. This is similar pattern as in the HDS neighborhoods. The lower income grouping residents are the ones who avail of this mode of travel the most. For the LDS neighborhoods, transit is not very prevalent as a mode of travel. Public transit use is minimal and in part because of the built environment of these neighborhoods, which makes mass transit provision in these urban built forms costly.

Environmental Burdens

The environmental burdens show similar trends as the driving patterns. Since the wealthier subgroup of residents in all three neighborhood types drive farther distances, they are responsible for the highest consumption levels of fuel and the highest emissions of carbon monoxide on an annual basis (grams per respondent). The vehicle characteristics of the wealthier residents play a role in this too. Larger and more powerful engines, larger sized vehicles, and driving conditions all affect fuel consumption and emissions. The wealthier residents are more likely to own powerful, faster, and larger vehicles, such as SUVs and minivans. These vehicle characteristics combined with the driving patterns are the variables that account for such high levels of fuel consumption and CO emissions.

In the *HDU neighborhoods*, the higher income subgroup drives about 3.5 times the distance (annual average per respondent to end-point destinations) that the lower income group does. Accordingly, the higher income grouping consumes 2.7 times the annual fuel (annual average gallons per respondent) and emits 2.6 times the carbon monoxide (annual average grams per respondent) than the lower income grouping in urban Detroit.

As far as the average fuel economy of the fleet of vehicles that each income group in urban Detroit owns, it becomes evident that the average fuel economy decreases as one moves from the lower income grouping to the upper income grouping. The average fleet fuel economy per respondent varies from 21.7 miles per gallon (low income group) to 20.5 miles per gallon for the middle income group and 20.4 miles per gallon for the upper income group. Similarly, the average fleet carbon monoxide emissions per respondent also increase from the lower income to the upper income groupings. The average carbon monoxide emissions for the lower income fleet was 4.3 grams per mile, for the middle income fleet it was 4.4 grams per mile, and for the upper income fleet it was 4.4 grams per mile.

In the *HDS neighborhoods*, when comparing the upper and lower income groupings, the upper income subgroup drives 2.3 times the distance for all trip purposes combined (annual average per respondent to end-point destinations), consumes 2.3 times more fuel (annual average gallons per respondent), and is responsible for about 2.2 times more emissions (annual average grams per respondent). The average fuel economy for the fleet shows the same trend (with the higher income groups being responsible for higher levels of environmental burdens), as fuel consumption varies from 23 miles per gallon for the lower income group, to 21.8 miles per gallon for the middle income group fleet and 20.7 miles per gallon for the upper income group fleet. The average carbon monoxide emissions range from 4.0 grams per mile for the lower income group fleet, to 4.2 grams per mile for the middle income fleet and 4.1 grams per mile for the upper income group fleet. These HDS neighborhoods shows similar trends for driving distance, fuel consumption and emissions as they generally depict that the wealthier consume more fuel and emit more pollutants.

For the last neighborhood typology, the *LDS neighborhoods*, similar trends continue, as the upper income group drives about 2.3 times the distance for all trip purposes combined (annual average per respondent), consumes 3 times the fuel (annual average gallons per respondent) and emits 2.6 times the pollutants (annual average grams per respondent) when compared to the lower income group. The proportionate increases in fuel consumption and emissions are also shaped by the vehicle characteristics. On average, the lower income subgroup fleet fuel efficiency is about 21 miles per gallon, while it is 20.7 miles per gallon for the middle income subgroup fleet and 19.2 miles per gallon for the upper income subgroup fleet. The average carbon monoxide emissions range from 4.0 grams per mile for the low income fleet, to 4.3 grams per mile for the middle income fleet and 4.2 grams per mile for the upper income fleet. These figures all point to the fact that as ones income increases, the vehicles that they own tend to be larger, more powerful and have higher energy requirements in travel. Within this neighborhood, we see once again, that there is a steady decline in fuel efficiency as the income range increases from the lowest to the highest income subgroups. Again, this positive trend between increasing environmental burdens and incomes is captured despite the fact that lower income groups have older vehicles that due to their lower technical sophistication will tend to generate higher MPGs and CO emissions.

All these results reiterate and stress the point that the wealthier drive farther distances, consume more fuel and are responsible for higher levels of emissions than lower income households, even when they live within the same built environment. This is a unique contribution of this analysis, since we are using performance characteristics of actual cars owned, with specific weight, engine, and power traits, best case emission levels pertaining to the specific make, model and year of the vehicle, and assigning them to a full array of driving destinations, including both work trips, non-work trips and all trips combined. This detail of analysis has not been provided in the existing literature and it is the unique and critical contribution of this work.

Chapter VII - Conclusion

Research on transportation issues has been conducted on a wide range of topics, from streetscape design to travel demand to transportation related greenhouse gas emissions and climate change. The latter issue has received considerable attention as global climate change and its vast consequences have been discussed with increasing fervor in recent years. With transportation, as an industry, being the fastest growing contributor of greenhouse gasses, studies relating to the planning and functioning of the urban built environment have focused on the transportation aspect for a deeper understanding of this industry's contribution to increasing greenhouse gasses.

Transportation topics have been researched at various geographical scales depending on the specific area of research. Greenhouse gas emissions and the transportation industry have typically been researched at larger geographic scales, such as national and state levels of scale. Travel demand and behavior studies typically focus on lower geographic scales, such as cities and travel analysis zones (TAZ). Road network and performance studies have been researched at the lowest scale, such as road and street network segments.

Travel behavior studies have typically looked at built environment characteristics of the area (usually robust neighborhoods or cities) and socio economic characteristics of residents to uncover how these affect travel demand and VMT. Greenhouse gas emission studies have focused on driving patterns, built environment characteristics and road networks to uncover how these variables affect emission levels. The gap in the literature, therefore, is the effects of the socio-economic characteristics of residents, including in neighborhoods experiencing disinvestment and decline, on travel behavior and the consequent environmental burdens, and specifically gasoline consumption and carbon monoxide (CO) emissions. This focus would help understand the travel behavior of residents with differing socio-economic characteristics and identify the set of characteristics that are responsible for higher levels of environmental burdens. Just as it is important to know the built environment characteristics that contribute to higher levels of emissions, so it is important to know the set of characteristics of people who contribute to higher levels of emissions (and fuel consumption).

Another important dimension of this research was the opportunity to gather primary data through a mail survey. Getting travel behavior data at the neighborhood scale is critical to transportation studies, and yet highly underrepresented, because this type of data collection is very time consuming and costly. This was an important reason for this particular study design: it would be completed with rich data, at a low scale, and fill a critical gap in the research.

Detroit, Michigan is a city in the US that has experienced unprecedented growth in the early 20th century on the basis of its manufacturing industry. Automobile manufacturing took the City to unprecedented heights, however, as business cycles go, this industry also experienced extensive economic downturns that crippled the City. With the economic engine suffering, other issues--such as suburbanization, segregation, crime, education, and poor policies--came to the forefront and wrapped the City in a self-perpetuating downward spiral. A study done in this unique City and its suburbs would add value in itself, given the conditions that neighborhoods in the City were experiencing, severe disinvestment and decline. Exploring travel behavior in communities experiencing disinvestment and decline is considered an under-represented aspect of urban geography and community planning.

The main research aim was to see if the built environment and socio-economic characteristics impact travel behavior and more specifically, environmental burdens (measured as vehicular fuel consumption and carbon monoxide (CO) emissions). The finer details involved analyzing how variations in socio-economic and demographic characteristics of residents living within the same built environment impacted travel and the consequent environmental burdens. This formed the crux of this study: to get an understanding of those resident characteristics that contributed to higher or lower environmental burdens, while also including within the study neighborhoods experiencing disinvestment and decline as well as robust and dynamic neighborhoods.

There were six neighborhoods involved in the study. These neighborhoods were grouped in twos (based on similar built environment characteristics) and were defined as three specific neighborhood typologies: the higher density urban (HDU) neighborhoods, the higher density suburban (HDS) neighborhoods, and the lower density suburban (LDS) neighborhoods. The two urban Detroit neighborhoods formed the HDU typology, Ann Arbor and Birmingham formed the HDS topology and Bloomfield Hills and West Bloomfield formed the LDS typology. The built environment characteristics that defined these groupings were density of structures, street network patterns, and the amount of and placements of mixed land uses.

A Discriminant Analysis was performed on the three typologies to see what the main factors were that distinguished the three neighborhood types. The results of the discriminant analysis stressed that the HDU neighborhood was different from the other two suburban neighborhoods based mainly on household income and educational attainment. In essence, the residents of the urban Detroit neighborhoods had lower educational attainment and lower household income compared to those of the suburban neighborhood residents.

The suburban neighborhoods differed from each other mainly based on the age of the residents, the share of non-work trips that are undertaken by walking, and the annual CO emissions. This result is telling as two of the three distinguishing factors between the two suburban neighborhood typologies relate to travel. Since the HDS neighborhoods are more compact, have higher accessibility and connectivity, more people can undertake their non-work trips by walking, and consequently, the residents in these neighborhoods are responsible for fewer annual environmental burdens (gasoline consumption and CO emissions). So a class dimension separates the Urban from the Suburban typologies, while a behavior dimension, a consequence of the different physical forms, separates the HDS from the LDS typologies.

The next analysis that was performed was a K-Means Cluster analysis on each of the three typologies. This analysis was conducted to see what groups the data themselves were forming. Two sets of Cluster Analyses were conducted on each of the three neighborhood typologies: the first Analysis was conducted on only the demographic variables, while the second Analysis was conducted on demographic as well as travel behavior variables. Since the typologies were already selected based on their built environment characteristics, the Cluster Analysis was conducted on the other variables (excluding the built environment characteristics) to see the types of groups that emerged within each typology.

The results of the <u>Cluster Analyses</u> on *demographic variables only* indicated that for the HDU typology, the groupings were mainly based on the number of dependents, the age of the residents, and whether they were employed for wages. The analysis done on the HDS typology resulted in groups that were mainly based on income, number of vehicles owned, age and usage of the primary vehicle used for travel, and the race of the respondent. The difference in the basis of the groups formed within the HDU and HDS typology shows that the prominent ranges in the

HDU typology were related to the class of the residents (income and education). The higher income among residents in the HDS typology resulted in groups based more on demographic factors. The results of the Cluster Analysis on the LDS typology indicated groups based on the number of dependents in the household, employment (for wages in general and in professional categories in particular) and the number of vehicles owned. The LDS groups show a smaller range of characteristics (like the HDU typology) that the groups were based on. The main difference being that employment (in professional categories) was also one of the main grouping factors.

The results of the Cluster Analyses on *demographic as well as travel behavior variables* indicated that for the HDU typology, groups were mainly based on travel behavior variables such as annual miles to work by walking, annual environmental burdens (fuel consumption and CO emissions), miles on vehicles, income and education. The analysis on the HDS typology revealed groups based on trips undertaken by different modes of travel (walking, transit and driving), and annual environmental burdens (fuel consumption and CO emissions).

The difference between the bases of clusters formed between the Higher Density Urban and Suburban typologies indicates that the HDS typology has a rich mix of amenities in proximity of the residential neighborhoods so as to give the residents the option of using the various modes of travel to get to various destinations. Fewer groups based on travel behavior for the HDU typology suggests that even though the typology has characteristics of high connectivity and access, there is not a good variety of travel options to realistically enable different modes of travel for the different trip purposes.

The results of the Cluster Analysis on the LDS typology indicated that the groups were based on trips undertaken by walking and driving, annual environmental burdens (fuel consumption and CO emissions), number of vehicles owned and the age and usage of the primary vehicle. These groupings are very similar to those that the HDS analysis resulted in, with an emphasis on mode of travel and environmental burdens. The difference being that the LDS typology had more grouping variables that related to the vehicles owned and used.

In summary the Cluster Analyses indicated that the HDS typology had a rich variation in the characteristics of the residents, and more specifically, a good variation in travel behavior. This is important because we can expect that residents living in the LDS typology neighborhoods use their vehicles for most of their travel purposes, however, residents living in the HDU typology neighborhoods confront similar built environment characteristics as residents living in the HDS typology neighborhoods and yet do not have this type of variation in their travel behavior. This distinction in the richness in travel behavior variation might be due to the fact that these HDU neighborhoods are experiencing disinvestment and decline and so there are not that many destinations and safe travel choices for the residents in these urban neighborhoods.

The last set of quantitative analyses conducted was the OLS Regressions and these were performed in order to test the hypotheses. The hypotheses essentially stated that within each neighborhood typology, the residents with higher socio-economic characteristics (higher incomes, higher levels of educational attainment, probability of being employed for wages, number of dependents, race and age of the respondent) would use their vehicles more than walking or using public transit for any and all of their travel purposes. Consequently, these residents would be responsible for higher levels of environmental burdens. In contrast, those residents with lower socio-economic characteristics would use other modes of transportation more often and use their vehicles for fewer miles and consequently be responsible for lower levels of environmental burdens. The hypotheses also stated that residents with higher socio-economic characteristics would own more vehicles per household, own newer vehicles and own vehicles with stronger engines compared to those with lower socio-economic characteristics (within the same neighborhood typology).

The regression results, in general, indicated an acceptance of the above hypotheses. Across all three neighborhoods, the main finding was that class had a significant relationship with travel patterns and environmental burdens. Even while living in the same neighborhood, people with different socio-economic characteristics behaved differently. The wealthier traveled more times and longer distances with their private vehicles compared to lower-income groups, and consequently, they were responsible for higher environmental burdens—higher gasoline consumption and CO emissions—despite the fact that the poorer households had older vehicles that are less fuel-efficient.

The regression analyses showed that after holding the built environment constant, socio-economic characteristics had significant relationships with travel behavior and environmental burdens, especially when it came to non-work trips and all trips combined. Age, as a socio-demographic variable, came out as significant in most of the regressions affecting travel. Older residents prefer to travel by car, over walking and transit, to reach their various destinations. Household income, education, and employment status (whether the respondent was employed for wages) consistently came out as significant for travel associated with public transit and driving. In general, the more educated, those with higher household incomes and respondents employed for wages, were likely to drive to destinations compared to those with lower values for those similar socio-economic characteristics. These residents were also, consequently, responsible for higher levels of environmental burdens, greater gasoline consumption and higher CO emissions.

One important aspect was that the variation in travel behavior by residents was significant for mainly those neighborhood typologies that had higher densities, mixed land uses, and higher connectivity (i.e. the HDU and the HDS neighborhoods). When it came to the LDS neighborhoods, the built environment was developed to facilitate automobile travel and therefore only the regressions on travel behavior for all trips combined and environmental burdens came out as significant. This is also an important aspect of this research. If the neighborhood typology itself has no options for alternative travel modes and destinations, then it forces everyone living in such environments to use their automobiles for any and all travel purposes. In the low density, single land use, and disconnected suburbs, the only way to move between daily destinations is by car.

To give the Regression analyses and overall results more meaning, each of the three typologies was broken down into three classes by the income of residents: categorizing them into Lower Income, Middle Income, and Higher Income groups. Travel behavior and environmental burdens were then categorized according to the income profile of the residents. What this did was provide a deeper, yet a more nuanced breakdown, of how residents with varying incomes, living in the same neighborhood, had differing travel behaviors and contributions to environmental burdens.

Across all three typologies, there was a constant recognition that the wealthier drive farther distances, consume more fuel and are responsible for higher levels of emissions than lower income households, even when they live within the same built environment. This is a unique contribution of this analysis, since we are using performance characteristics of actual cars owned, with specific weight, engine, and power traits, best case emission levels pertaining to the specific make, model and year of the vehicle, and assigning them to a full array of actual driving destinations by households, including work trips and non-work trips.

Another important contribution of this work is bringing the issue of 'class' to the forefront of travel behavior analysis. This issue has been dealt with in the literature by looking at the travel behavior (not environmental burdens as a result of the travel behavior) of entire neighborhoods with similar class structures. This study shows that even the relatively wealthier population living in declining neighborhoods contributes more to environmental burdens than the poorer residents in the same neighborhoods. In addition to the specific case of including neighborhoods experiencing extreme decline, there is a variation in class structure within all neighborhood typologies. Simply, the wealthier, whether they live in robust communities or in neighborhoods experiencing disinvestment and decline, travel more often and further distances by car and are responsible for higher levels of environmental burdens.

These results reveal that, even in neighborhoods that would generally be looked at as maintaining a similar class characteristic, the more subtle class variations within the neighborhood generate significant differences in travel behavior and resulting environmental burdens. This is a novel contribution to the existing study of travel behavior, and particularly in the context of analyzing gasoline consumption and CO emissions. This has never previously been examined in travel behavior research that has focused on environmental burdens, including gasoline consumption and/or pollutant emissions.

An important recognition should be made with regard to the impact of neighborhood disinvestment and decline on neighborhood access to daily destinations. Travel behavior studies have shown that lower income residents travel further distances (especially for work based trips). They also tend to live in inner city areas so that they can avail of alternative travel modes to get to destinations, as they are less likely to own vehicles (Grengs, 2012; Pendall, 2000; Squires and Kubrin, 2005). This study also shows that even though the lower income population lives in urban Detroit areas characterized by high-densities, high-connectivity and mixed land uses, the extensive disinvestment within these neighborhoods have increased travel distances to a variety of destinations, including amenities that would be considered necessary daily destinations. In fact, for Detroit urban residents—despite the higher-density, greater land-use mix and higher-connectivity, which are neighborhood characteristics that should improve access—distances to reach shopping, personal services, and leisure destinations are similar to those of residents living in isolated, disconnected, residential neighborhoods in the low-density Detroit suburbs.

For example, the average distance to national/regional supermarkets is higher for the Detroit urban residents (5.5 miles) than for the low-density suburban residents (3.1 miles), indicating that these stores are locating away from the inner city and closer to the wealthier, low-density suburban neighborhoods. In fact, for all store types combined, the urban Detroit residents travel about the same average distances for retail/grocery shopping as do the low-density suburban residents (3.3 miles and 3.4 miles respectively). Similarly, for personal services, the Detroit residents and the low-density suburban residents travel about the same average distances (3.4 miles and 3.5 miles respectively). There has been such extensive disinvestment in the high-density Detroit urban neighborhoods that they face comparable, and sometimes even longer distances, to daily destinations when compared to residents living in the low-density, isolated Detroit suburbs.

The lower income eastside Detroit residents face a greater burden, in terms of travel distances, to reach basic daily necessities not because of the urban built environment, but because of the lack of availability of adequate destination choices in proximity to their homes. What the extreme disinvestment and decline in Detroit has accomplished is to transform, what are traditionally viewed as high-accessibility urban neighborhoods, into low-density suburbs, at least in terms of accessibility characteristics. However, despite these similarities in distances to destinations between the lower-income Detroit urban respondents and the upper-income, low-density Detroit suburban respondents, the higher income suburban respondents—on an annual basis—travel about twice the distances by car, consume about twice the gasoline (gallons per year), and emit about two times the CO levels associated with automobile travel. It is thus at multiple dimensions that we can conclude that environmental burdens associated with travel are shaped by class, with higher income earners disproportionately contributing to negative anthropogenic environmental impacts.

This study is important on a number of dimensions. First and most importantly, it contributes to a gap in the research on the social impacts on travel and environmental burdens. Secondly, it combines qualitative and quantitative analyses to help understand the various nuances of the effects of class on travel and environmental burdens. Both these types of analyses are distinct and have critical contributions to the existing research in geography, urban planning, urban design and economics, and as such, are important in their own respects. Thirdly, this study is important to multiple target agencies, officials and researchers, such as transportation planners, researchers on sustainability issues, environmental planning and urban planning professionals and policymakers.

There are a number of policy implications of this research and its outcomes. One addresses the current policy debate in Michigan on how the revenue generation for road repair should be collected from the Michigan population. It is a highly controversial issue that will go to the ballots in November of 2013, if approved by the Senate. Governor Snyder has proposed to the raise the Michigan gas tax in order to raise $1.2 billion annually for road improvements. The increase in the gas tax (currently from 19 cents per gallon for gasoline and 15 cents per gallon for diesel to about 33 cents for both fuels) would put the responsibility of maintaining Michigan roads on those who use them. Opposing lawmakers, on the other hand, have suggested an alternative way to raise funds -- cancel the sales tax on gasoline and increase the gas tax by the same amount as the sales tax (so that people do not pay more at the pump). They have also suggested an increase in the overall state sales tax (of about 1-2 percent) to make up for the loss in sales tax revenue from fuel sales (this would also lead to an overall increase in tax revenue that would go to education and revenue sharing) (Eggert, 2013; Oosting, 2013).

This research has shown that the lower the income among the population, the more that they will tend to walk and the more that they will tend to drive fewer miles in comparison to their wealthier counterparts. A flat sales tax across the Michigan population would remove the onus from those who use the roads most, and spread the cost of maintaining roads and highways to all Michigan residents, which would disproportionately burden the Michigan lower-income population who do not use cars as much for their travel needs. In the context of the considerable diversity in automobile use by income, and given that road use by automobile travel has clear cost implications linked to those populations driving, policy would need to be introduced that would ensure a costing structure based as closely as possible on marginal costs (Vojnovic, 2000). This would require very clear relationships to be established between car use, road use (along with its wear-and-tear), and revenue collection for road and highway repairs. Without the tax on road repair linked to gasoline consumption, both inefficiencies and inequities would be generated within Michigan's public revenue and service delivery structure. This would be realized with Michigan lower income populations paying for services delivered, maintained and consumed--in this case, roads/highways and their maintenance--disproportionately by the Michigan wealthy (Vojnovic 1999, 2000a, 2000b).

The findings from this study also provide policy insight into the existing structure of the Gas Guzzler Tax. The Gas Guzzler tax was originally implemented in 1978 and is a tax that is placed on manufacturers for sales of vehicles that do not meet the minimum 22.5 miles per gallon fuel efficiency (EPA, 2012). An important aspect of this tax is that it is not levied on SUVs, minivans and pickup trucks. These vehicles are a major part of the US passenger vehicle fleet and they are known to be larger vehicles and typically consume higher levels of fuel and emit higher levels of pollutants. These vehicles, as my research has shown, also tend to be driven by the wealthier population, and also over longer distances.

These vehicles were not included in the Energy Tax Act because in 1978 they formed a very small proportion of the US vehicle fleet. However, the use of these vehicles is much more extensive now and the Gas Guzzler tax should be reflective of this. If the U.S. is to seriously address greenhouse gas emissions, the federal government needs to expand the Energy Tax Act to include the most serious gasoline consumers and pollutant emitters. There is no reason to exempt SUVs, minivans and pickup trucks from national efforts to reduce Greenhouse Gas

Emissions, and particularly given that these vehicles are associated with the most significant environmental impacts and are driven disproportionately by the wealthy.

This study brings together multiple fields and can lead to many more collaborative studies and research on social characteristics, environmental and climate change issues, transportation planning and the urban built environment. By using actual data on the full-array of travel behavior, along with automobile ownership characteristics at the household level, a unique perspective is provided on fuel consumption and vehicle emissions. This environmental and travel data has the added advantage of being tied to socio-economic and demographic household characteristics. This research provides important insight to policymakers that can be used to shape both local public finances associated with road provision and maintenance, and also environmental policy tied to the growing global interest in Greenhouse Gas Emissions. What becomes evident along both lines of policy is the political interest in exempting the wealthy from being responsible for their disproportionate scales of resource consumption and environmental burdens.

Future Research Possibilities

Future research on this topic could explore in more detail the variables that impact travel behavior for work trips. This study had several regressions that turned out insignificant for socio-economic characteristics and work based trips. The reason for this could be that residents have less of a choice in mode of travel and the distance they travel to work that can be impacted by socio-economic characteristics. Lower income and minority populations have more limited job options and have less of a choice on where their place of employment would be. The higher income residents do have and exercise greater choice in terms of where they live and work. A further study into work based trips and environmental burdens would be useful. In addition, the regression analyses resulted in low adjusted R-squares. This indicates that the models explained a small part of the variation in travel behavior and environmental burdens. This would need to be further investigated and other factors that determine travel behavior would need to be included in future models to assess the explanatory power of the models. Other socio-economic factors, such as family structure and gender, and other built environment factors, such as connectivity, accessibility and density, could be included in models to determine if these help in explaining a greater proportion of the variation in travel behavior and environmental burdens.

In addition, a deeper analysis of the contributions of race to travel behavior and environmental burdens would also be important. Although this study did include variables of race within the analyses, there were just not that much of variation among the population to account for a full analysis. Within the Detroit neighborhoods, there were too few whites and within the LDS neighborhoods, there were too few blacks. The 'other' race faced the same issues as well, a result of the well-known racial polarization of these areas. A study that would include a larger variation and number of residents of different races would be useful in determining the contributions of this important variable to the environmental burdens discourse.

Apart from this study making critical contributions to existing research, it has tremendous potential for future research as well. The detailed dataset that this study comes from has the potential to extend the environmental burdens analysis to different trip destinations, different geographic scales and social characteristics. Future potential areas of research include analyzing environmental burdens at an individual/household level of scale emphasizing built environment impacts on environmental burdens. This will be done by examining the built environment within a half mile buffer zone around each household and examine the impacts of the personal built environment factors on travel behavior and environmental burdens.

Another potential research opportunity would include a merger of gender and family structure characteristics on environmental burdens. This would allow an analysis into the differing environmental burdens between men and women. Yet another opportunity would be an analysis of environmental impacts broken down into a greater variety of trip destinations than just the work, non-work and all destinations included in this study. In short, these data sets and the study of environmental burdens have the potential for research that can add to the existing understanding of environmental impacts, and especially given the sorely lacking and underrepresented dimension of this research direction at the household level and the neighborhood scale.

APPENDICES

APPENDIX A - Data Validation

Table 57: Data Validation - Detroit

Demographic Characteristic	Detroit		
	Detroit City	2010 Census Tracts (encompassing the neighborhood)	Study Survey
Race			
% White	8%	5%	8%
% Black	82%	93%	90%
% Other	10%	2%	2%
Income			
Mean Household	$39,327	$31,863	$28,102
Per Capita	$15,261	$12,834	$21,809

Table 58: Data Validation – Ann Arbor

Demographic Characteristic	Ann Arbor		
	Ann Arbor City	2010 Census Tracts (encompassing the neighborhood)	Study Survey
Race			
% White	70%	84%	94%
% Black	8%	5%	2%
% Other	22%	11%	4%
Income			
Mean Household	$77,239	$77,975	$88,160
Per Capita	$32,734	$34,937	$54,926

Table 59: Data Validation – Birmingham

Demographic Characteristic	Birmingham		
	Birmingham City	2010 Census Tracts (encompassing the neighborhood)	Study Survey
Race			
% White	91%	93%	94%
% Black	3%	3%	1%
% Other	6%	4%	5%
Income			
Mean Household	$151,887	$166,467	$113,896
Per Capita	$67,580	$72,079	$73,869

Table 60: Data Validation – Bloomfield Hills

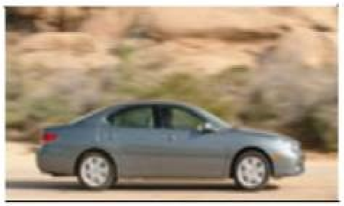
Demographic Characteristic	Bloomfield Hills		
	Bloomfield Hills City	2010 Census Tracts (encompassing the neighborhood)	Study Survey
Race			
% White	86%	85%	92%
% Black	4%	5%	1%
% Other	10%	10%	7%
Income			
Mean Household	$211,077	$209,541	$109,278
Per Capita	$79,184	$81,551	$73,933

Table 61: Data Validation – West Bloomfield

Demographic Characteristic	West Bloomfield		
	City	2010 Census Tracts (encompassing the neighborhood)	Study Survey
Race			
% White	77%	73%	84%
% Black	11%	14%	5%
% Other	12%	13%	11%
Income			
Mean Household	$127,804	$122,077	$106,758
Per Capita	$47,269	$43,488	$69,118

Appendix B – Example of EPA Window Sticker

Figure 34: Example of an EPA Window Sticker



2005 LEXUS ES 330
Printable Car Buyer's Check Sheet

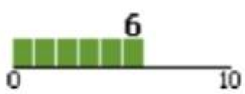
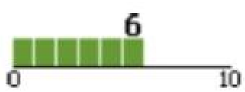
Vehicle Specifications	
Engine:	3.3 Liter, 6 cylinder
Engine Horse Power:	
Transmission:	Auto 5 speed -
Fuel Type:	Gasoline
Drive:	2WD
Vehicle Type:	Midsize Cars
Environmental Information	
Air Pollution Score: 10 = best	
Greenhouse Gas Score: 10 = best	
SmartWay:	No
City Fuel Economy: (miles per gallon)	18
Highway Fuel Economy: (miles per gallon)	27
Combined Fuel Economy: (miles per gallon)	21
Fuel Consumption: (gallons per 100 miles)	4.76
Estimated Annual Fuel Cost: ($ dollars)	1893
Certification Sales Region:	Federal All Altitude

Figure 34 (cont'd)

Emissions Certification Standard:	Bin 5
Standards (grams per mile)	
NOx	0.07
CO	4.2
NMOG	0.09
PM	0.01
Smog-forming Pollution: (pounds per year)	5.29
Greenhouse Gases Emitted: (tons per year)	7.03
Other Information	
Underhood Label ID:	5TYXV03.3PEA
Turbo / Supercharger:	NONE
Engine Descriptor:	
Valves per Cylinder:	4
Transmission Overdrive:	TOP GEAR RATIO < 1
Number of Transmission Modes:	1 DISCRETE USER-SELECTABLE TRANSMISSION MODE
Variable Lock-up Point:	COMPUTER CONTROLLED LOCKUP
Declutching/Freewheeling:	NO
Passsenger Volume : (cubic feet)	96.398
Luggage Volume : (cubic feet)	14.548
Fuel Usage:	

Appendix C – Example of Fuel Economy from the Department of Energy

Figure 35: Example of a Fuel Economy Sheet

Personalize	**2005 Lexus ES 330** X  3.3 L, 6 cyl, Automatic 5-spd
EPA Fuel Economy	
Miles per Gallon	**REGULAR GASOLINE** **21** Combined **18** City **27** Highway 4.8 gallons/100 mi
MPG estimates for 2007 and older vehicles have been revised	View Original EPA MPG
Unofficial MPG Estimates from Vehicle Owners	
Learn more about "Your MPG" Disclaimer	Average based on 7 vehicles **24.9** **21** Lo **29** Hi
	View Individual Estimates
Fuel Economics	
You save or spend* Note: The average 2013 vehicle gets 23 MPG	**You SPEND $1,250** more in fuel costs over 5 years compared to the average new vehicle
Annual Fuel Cost*	$2,550
	REGULAR GASOLINE
Cost to Drive 25 Miles	$4.21
Fuel to Drive 25 Miles	1.2 gallons
Cost to Fill the Tank	$59
Miles on a Tank	350 miles
Tank Size	18.5 gallons

*Based on 45% highway, 55% city driving, 15,000 annual miles and current fuel prices. Personalize.

MSRP and tank size data provided by Edmunds.com, Inc.

Miles on a tank and refueling costs assume 90% of fuel in tank will be used before refueling.

Appendix D – Code Book

Table 62: Code Book

CODE	NAME	DESCRIPTION	SOURCE
Demographic Variables			
Age	Age	Age of respondent in years	Survey
PIncome	Personal Income	Mean values of Personal Income Ranges on the survey	Computed from survey
HIncome	Household Income	Mean values of Household Income Ranges on the survey	Computed from survey
Educ	Educational Attainment	Years of formal education received	Computed from survey
Inc_Supports	Income Supports	Number of people the household income supports	Survey
Num_Child	Number of Children	Number of children under the age of 18 years living at home	Survey
Vehicle Variables			
VehYou	Vehicles for you	Number of vehicles for use by respondent primarily	Survey
VehAll	Vehicles for all	Number of vehicles for use by all in the household	Survey
VehYear	Vehicle Year	Year of the Vehicle Model	Survey/MI SOS
VehCylinder	Cylinders	Number of cylinders in Vehicle Engine	Survey/MI SOS
VehMiles	Mileage	Number of miles on vehicle	Survey
Travel Variables			
Pct_WorkTrips_Walk	Percent Work Trips Walk	Percent of all trips to work undertaken by walking	Computed from survey
Pct_WorkTrips-Drive	Percent Work Trips Drive	Percent of all trips to work undertaken by driving	Computed from survey

Table 62 (cont'd)

Pct_NonWorkTrips_Walk	Percent Non-Work Trips Walk	Percent of all trips to non-work destinations undertaken by walking	Computed from survey
Pct_NonWorkTrips_Drive	Percent Non-Work Trips Drive	Percent of all trips to non-work destinations undertaken by driving	Computed from survey
Pct_AllTrips_Transit	Percent All Trips Transit	Percent of all trips to all destinations undertaken by public transit	Computed from survey
Ann_WorkMiles_Walk	Annual Work Miles Walk	Total annual miles for all trips to work undertaken by walking	Computed from survey
Ann_WorkMiles_Transit	Annual Work Miles Transit	Total annual miles for all trips to work undertaken by Public Transit	Computed from survey
Ann_WorkMiles_Drive	Annual Work Miles Drive	Total annual miles for all trips to work undertaken by Driving	Computed from survey
Ann_NonWorkMiles_Walk	Annual Non-Work Miles Walk	Total annual miles for all trips to non-work destinations undertaken by walking	Computed from survey
Ann_NonWorkMiles_Transit	Annual Non-Work Miles Transit	Total annual miles for all trips to non-work destinations undertaken by Public Transit	Computed from survey
Ann_NonWorkMiles_Drive	Annual Non-Work Miles Drive	Total annual miles for all trips to non-work destinations undertaken by Driving	Computed from survey
Ann_AllMiles_Walk	Annual All Miles Walk	Total annual miles for all trips to all destinations undertaken by walking	Computed from survey
Ann_AllMiles_Transit	Annual All Miles Transit	Total annual miles for all trips to all destinations undertaken by Public Transit	Computed from survey

Table 62 (cont'd)

Ann_AllMiles_Drive	Annual All Miles Drive	Total annual miles for all trips to all destinations undertaken by Driving	Computed from survey
Ann_Fuel_Consump	Annual Fuel Consumption	Total annual gallons of fuel consumption	Computed from survey and EPA's Office of Transportation and Air Quality (OTAQ) site on Green Vehicle Guide (http://www.epa.gov/greenvehicles/Index.do)
Ann_CO_Emissions	Annual Carbon Monoxide Emissions	Total annual grams of Carbon Monoxide emissions	Computed from survey and EPA's Office of Transportation and Air Quality (OTAQ) site on Green Vehicle Guide (http://www.epa.gov/greenvehicles/Index.do)

Appendix E – Distributions of Variables (for Discriminant Analysis)

The Discriminant Analysis was conducted on one single file that had all three neighborhood types coded from 1 to 3 (1=HDU, 2=HDS, and 3=LDS)

The stepwise DA (Discriminant Analysis) chose the following variables.

Table 63: Results of Stepwise DA

Variable	N	Minimum	Maximum	Mean	Skewness	Kurtosis
VehAll	774	0	9	1.85	0.70	3.44
Age	939	18	94	53.27	0.04	-0.61
HIncome	825	5000	155000	83981.82	0.03	-1.38
Educ	942	10	19	15.96	-0.47	-1.10
Inc_Supports	899	0	10	2.49	0.87	0.70
Pct_NonWork_ Trips_Walk	936	0	100	16.84	1.65	1.79
Ann_CO_Emissions	793	0	439966.80	12401.97	10.79	175.80

For normally distributed variables, the skewness and kurtosis numbers should fall between -1.0 and +1.0. After trying different transformations (log normal, square root, and inverse), the following transformed variables were used for the DA.

Table 64: Transformed Variables used in DA

Variable	N	Minimum	Maximum	Mean	Skewness	Kurtosis
LnVehAll	705	0.00	2.20	0.62	-0.12	-0.45
Age	939	18.00	94.00	53.27	0.04	-0.61
Sqrt_HIncome	825	70.71	393.70	270.61	-0.44	-0.97
Ln_Educ	942	2.30	2.94	2.75	-0.69	-0.73
Inc_Supports	899	0	10.00	2.49	0.87	0.70
Ln_Pct_NonWork_ Trips_Walk	390	0.21	4.61	3.42	-0.66	0.09
Ln_Ann_CO_Emissions	743	3.61	12.99	8.82	-0.41	0.45

Appendix F – Distributions of Variables (for Regression Analyses)

The Regression Analyses were conducted on three separate files corresponding to the three neighborhood typologies (HDU, HDS, and LDS). The following tables represent the distributions for the variables that were measured on a scale/ratio basis used in the regressions.

Table 65: Original Distribution of Variables - HDU Neighborhoods

Variable	N	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Age	227	18	94	52.10	264.42	-0.058	-0.508
HIncome	201	5000	135000	30422.89	7.78	1.458	2.066
Educ	225	10	19	12.95	1.46	1.093	0.470
Num_Child	208	0	8	0.87	1.91	1.769	3.322
Pct_WTrips_W	93	0	100	13.50	721.73	2.01	3.23
Pct_WTrips_T	93	0	100	13.46	784.10	1.99	2.77
Pct_WTrips_D	93	0	100	73.04	1558.28	-0.99	-0.71
Pct_OptTrips_W	220	0	100	23.63	1157.80	1.19	0.00
Pct_OptTrips_T	220	0	100	8.31	391.09	3.03	9.71
Pct_OptTrips_D	220	0	100	68.06	1549.43	-0.75	-1.08
Pct_AllTrips_W	223	0	100	22.97	1080.52	1.28	0.29
Pct_AllTrips_T	223	0	100	9.84	459.12	2.72	7.56
Pct_AllTrips_D	223	0	100	67.19	1546.49	-0.74	-1.11
Ann_WMiles_W	93	0	10244	287.15	1541254.9	6.48	47.54
Ann_WMiles_T	93	0	10244	299.31	1718341.1	6.17	41.56
Ann_WMiles_D	93	0	25953	1849.67	11770138.1	4.41	26.65
Ann_OptMiles_W	220	0	13010	224.40	955502.8	10.83	136.32
Ann_OptMiles_T	220	0	12766	259.65	1097011.4	8.77	96.29
Ann_OptMiles_D	220	0	11318	1214.64	2911302.1	2.70	9.71
Ann_AllMiles_W	223	0	15844	341.14	2108656.2	8.26	77.06
Ann_AllMiles_T	223	0	15917	380.98	2642589	8.04	72.21
Ann_AllMiles_D	223	0	26411	1969.69	10298916.2	3.62	18.79
Ann_Fuel_Consumption	105	1.49	1049.53	137.60	26578.3	2.97	10.88
Ann_CO_Emissions	105	131.04	72825.48	11931.21	1.705E8	2.15	5.28

The above variables were transformed to the following to get as close to a normal distribution as possible:

Table 66: Transformed Distribution of Variables - HDU Neighborhoods

Variable	N	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Age	227	18	94	52.10	264.42	-0.06	-0.51
Ln_Hshld_Income	201	8.52	11.81	9.88	1.01	-0.11	-1.21
Ln_Educ	225	2.30	2.94	2.54	0.03	0.74	-0.10
Sqrt_Num_Child	208	0.00	2.83	0.55	0.57	0.89	-0.72
Pct_WTrips_W	93	0	100	13.50	721.73	2.01	3.23
Pct_WTrips_T	93	0	100	13.46	784.10	1.99	2.77
Pct_WTrips_D	93	0	100	73.04	1558.28	-0.99	-0.71
Pct_OptTrips_W	220	0	100	23.63	1157.80	1.19	0.00
Pct_OptTrips_T	220	0	100	8.31	391.09	3.03	9.71
Pct_OptTrips_D	220	0	100	68.06	1549.43	-0.75	-1.08
Pct_AllTrips_W	223	0	100	22.97	1080.52	1.28	0.29
Pct_AllTrips_T	223	0	100	9.84	459.12	2.72	7.56
Pct_AllTrips_D	223	0	100	67.19	1546.49	-0.74	-1.11
LnAnn_WMiles_W	93	0	9.23	0.98	6.00	2.26	3.49
LnAnn_WMiles_T	93	0	9.23	0.95	5.96	2.31	3.71
LnAnn_WMiles_D	93	0	10.16	4.75	13.24	-0.41	-1.61
LnAnn_OptMiles_W	220	0	9.47	2.12	7.45	0.72	-1.10
LnAnn_OptMiles_T	220	0	9.45	1.33	7.07	1.62	0.88
LnAnn_OptMiles_D	220	0	10.46	5.42	8.17	-1.00	-0.29
LnAnn_AllMiles_W	223	0	9.67	2.27	8.15	0.69	-1.07
LnAnn_AllMiles_T	223	0	9.68	1.51	7.99	1.47	0.44
LnAnn_AllMiles_D	223	0	10.18	5.68	8.91	-0.99	-0.29
LnAnn_Fuel_Consumption	105	0.91	6.96	4.24	1.63	-0.28	-0.52
LnAnn_CO_Emissions	105	4.88	11.20	8.69	1.76	-0.42	-0.30

Table 67: Original Distribution of Variables - HDS Neighborhoods

Variable	N	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Age	391	19	90	50.99	262.37	0.29	-0.65
HIncome	347	5000	155000	96123.92	2.178E9	-0.185	-1.19
Educ	389	12	19	17.08	5.23	-0.91	-0.19
Num_Child	377	0	3	0.54	0.81	1.44	0.75
Pct_WTrips_W	265	0	100	16.03	961.31	1.84	2.02
Pct_WTrips_T	265	0	100	6.66	374.04	3.16	9.72
Pct_WTrips_D	265	0	100	77.30	1377.85	-1.26	-0.09
Pct_OptTrips_W	389	0	100	21.47	733.74	1.19	0.53
Pct_OptTrips_T	389	0	100	1.13	41.96	8.22	78.04
Pct_OptTrips_D	389	0	100	77.39	802.75	-1.19	0.48
Pct_AllTrips_W	392	0	100	20.12	637.88	1.28	0.81
Pct_AllTrips_T	392	0	100	2.83	89.36	4.23	20.56
Pct_AllTrips_D	392	0	100	77.05	772.98	-1.13	0.24
Ann_WMiles_W	265	0	7041	130.68	451257.6	8.22	71.23
Ann_WMiles_T	265	0	4264	64.18	128528.9	9.72	103.75
Ann_WMiles_D	265	0	17602	1926.99	7621591.4	2.22	6.29
Ann_OptMiles_W	391	0	4581	99.89	89325.6	9.86	133.99
Ann_OptMiles_T	391	0	1006	9.13	3747.2	12.33	186.02
Ann_OptMiles_D	391	0	6750	855.59	803207.2	2.65	10.53
Ann_AllMiles_W	392	0	7066	187.98	408523.9	7.48	64.28
Ann_AllMiles_T	392	0	4264	52.49	92734.3	11.00	137.71
Ann_AllMiles_D	392	0	18502	2156.09	6725655.6	2.42	7.85
Ann_Fuel_Consumption	347	0.44	925.11	108.76	16728.9	2.36	7.38
Ann_CO_Emissions	347	37.13	77708.90	9098.97	1.188E8	2.46	8.06

The above variables were transformed to the following to get as close to a normal distribution as possible:

Table 68: Transformed Distribution of Variables - HDS Neighborhoods

Variable	N	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Age	391	19	90	50.99	262.37	0.29	-0.65
Sqrt_HIncome	347	70.71	393.70	298.01	7337.7	-0.70	-0.27
Educ	389	12	19	17.08	5.23	-0.91	-0.19
Sqrt_Num_Child	377	0	1.73	0.40	0.38	1.03	-0.70
Pct_WTrips_W	265	0	100	16.03	961.31	1.84	2.02
Pct_WTrips_T	265	0	100	6.66	374.04	3.16	9.72
Pct_WTrips_D	265	0	100	77.30	1377.85	-1.26	-0.09
Pct_OptTrips_W	389	0	100	21.47	733.74	1.19	0.53
Pct_OptTrips_T	389	0	100	1.13	41.96	8.22	78.04
Pct_OptTrips_D	389	0	100	77.39	802.75	-1.19	0.48
Pct_AllTrips_W	392	0	100	20.12	637.88	1.28	0.81
Pct_AllTrips_T	392	0	100	2.83	89.36	4.23	20.56
Pct_AllTrips_D	392	00	100	77.05	772.98	-1.13	0.24
LnAnn_WMiles_W	265	0	8.86	1.26	5.52	1.47	0.59
LnAnn_WMiles_T	265	0	8.36	0.69	3.52	2.47	4.60
LnAnn_WMiles_D	265	0	9.78	5.61	9.31	-0.95	-0.45
LnAnn_OptMiles_W	391	0	8.43	2.12	6.13	0.49	-1.43
LnAnn_OptMiles_T	391	0	6.91	0.26	1.20	4.09	15.60
LnAnn_OptMiles_D	391	0	8.82	6.10	2.58	-2.30	6.26
LnAnn_AllMiles_W	392	0	8.86	2.45	7.08	0.40	-1.41
LnAnn_AllMiles_T	392	0	8.36	0.65	3.21	2.56	5.05
LnAnn_AllMiles_D	392	0	9.83	6.93	2.41	-1.85	6.42
LnAnn_Fuel_Consumption	347	0.37	6.83	4.10	1.33	-0.21	0.01
LnAnn_CO_Emissions	347	3.64	11.26	8.49	1.45	-0.42	0.65

Table 69: Original Distribution of Variables - LDS Neighborhoods

Variable	N	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Age	317	18	92	57.04	226.0	-0.12	-0.41
HIncome	273	5000	155000	108516.48	2.012E9	-0.50	-1.01
Educ	324	10	19	16.75	6.35	-0.85	-0.20
Num_Child	314	0	4	0.65	1.02	1.30	0.41
Pct_WTrips_W	196	0	100	5.53	348.0	3.94	15.86
Pct_WTrips_T	196	0	16.67	0.09	1.41	14.00	196.00
Pct_WTrips_D	196	0	100	94.38	348.47	-3.92	15.74
Pct_OptTrips_W	323	0	87.50	6.83	236.78	2.76	7.79
Pct_OptTrips_T	323	0	27.27	0.18	3.43	12.15	159.82
Pct_OptTrips_D	323	12.50	100	92.99	238.82	-2.71	7.50
Pct_AllTrips_W	325	0	83.12	6.92	220.36	2.75	7.97
Pct_AllTrips_T	325	0	27.27	0.20	3.57	11.52	146.34
Pct_AllTrips_D	325	16.88	100	92.88	222.49	-2.69	7.63
Ann_WMiles_W	196	0	7072	88.59	305884.6	10.81	132.44
Ann_WMiles_T	196	0	572	2.92	1669.3	14.00	196.00
Ann_WMiles_D	196	0	69940	3354.82	37357268.9	8.05	80.17
Ann_OptMiles_W	324	0	2803	68.11	80199.5	6.79	54.17
Ann_OptMiles_T	324	0	577	2.28	1066.8	17.07	299.95
Ann_OptMiles_D	324	0	18153	1921.06	3891470.3	3.41	19.01
Ann_AllMiles_W	325	0	7072	121.32	261892.6	9.13	109.68
Ann_AllMiles_T	325	0	577	4.03	2062.2	12.35	153.75
Ann_AllMiles_D	325	0	72868	3938.36	29228784.5	7.88	89.60
Ann_Fuel_Consump	284	4	4858	214.42	124629.4	9.27	111.50
Ann_CO_Emissions	284	349	181687	16428.26	3.397E8	4.55	32.85

The above variables were transformed to the following to get as close to a normal distribution as possible:

Table 70: Transformed Distribution of Variables - LDS Neighborhoods

Variable	N	Minimum	Maximum	Mean	Variance	Skewness	Kurtosis
Age	317	18	92	57.04	-0.12	-0.12	-0.41
Sqrt_HIncome	273	70.71	393.70	320.05	6107.5	-0.94	0.11
Educ	324	10	19	16.75	-0.85	-0.85	-0.20
Sqrt_Num_Child	314	0	2	0.46	0.44	0.86	-1.02
Pct_WTrips_W	196	0	100	5.53	348.0	3.94	15.86
Pct_WTrips_T	196	0	16.67	0.09	1.41	14.00	196.00
Pct_WTrips_D	196	0	100	94.38	348.47	-3.92	15.74
Pct_OptTrips_W	323	0	87.50	6.83	236.78	2.76	7.79
Pct_OptTrips_T	323	0	27.27	0.18	3.43	12.15	159.82
Pct_OptTrips_D	323	12.50	100	92.99	238.82	-2.71	7.50
Pct_AllTrips_W	325	0	83.12	6.92	220.36	2.75	7.97
Pct_AllTrips_T	325	0	27.27	0.20	3.57	11.52	146.34
Pct_AllTrips_D	325	16.88	100	92.88	222.49	-2.69	7.63
LnAnn_WMiles_W	196	0	8.86	0.52	3.13	3.25	9.10
LnAnn_WMiles_T	196	0	6.35	0.03	0.21	14.00	196.00
LnAnn_WMiles_D	196	0	11.16	6.68	8.01	-1.62	1.39
LnAnn_OptMiles_W	324	0	7.94	0.98	4.19	1.85	1.98
LnAnn_OptMiles_T	324	0	6.36	0.05	0.24	10.84	120.38
LnAnn_OptMiles_D	324	0	9.81	7.12	1.22	-1.87	9.84
LnAnn_AllMiles_W	325	0	8.86	1.23	5.3	1.59	1.00
LnAnn_AllMiles_T	325	0	6.36	0.06	0.36	9.32	87.80
LnAnn_AllMiles_D	325	0	11.20	7.76	1.43	-1.85	9.76
LnAnn_Fuel_Consumption	284	1.68	8.49	4.85	1.09	-0.28	0.13
LnAnn_CO_Emissions	284	5.86	12.11	9.24	1.06	-0.40	-0.15

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