Impacts of Residential Developments on Local Sustainability:  
A Case Study in Metro Boston

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Abstract

Along with urbanization and decentralization, the sustainability of metropolitan areas is considered one of the most significant challenges worldwide. Transportation-related problems, such as congestion, GHG emissions, and excessive energy consumption, have been imposing tremendous pressure on the sustainability of metropolitan areas. As a noticeable component of urban form, local residential developments may have great influence on local and regional sustainability. However, few studies have addressed the impacts of individual residential development projects on local sustainability and the underlying implications for regional plans in detail.

The purpose of this study is to propose an analytical framework that can reveal different transport-related impacts of individual residential developments located in different types of communities, to examine whether new residents have travel patterns similar to existing residents, and to explore why such impacts differ across the selected developments by analyzing the built environment characteristics of each development.

Nine residential developments constructed during 2000~2005 have been selected based on various criteria. Two Vehicle Miles Traveled (VMT) indicators - VMT per vehicle and VMT per household – are computed to represent the level of sustainability for each development. The study also estimates the average VMT indicators for the neighboring areas (750m buffer areas) and the towns where the selected projects are located. A comparison of the results suggests that residential developments do have different impacts on local sustainability in terms of VMT indicators and that new residents do not always have travel patterns exactly the same as those of existing residents.

The built environment characteristics of the development areas, their surrounding areas, and their towns are investigated to analyze why the transport-related consequences vary across the selected developments. Some indicators are calculated including densities (population density and road density), land-use mix, location (distances to public transit and major roads), and other factors (job accessibility and neighborhood building age). The results illustrate that population density, land-use mix, distance to major roads, and job accessibility have greater influence over resultant VMT variations.

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Title: Senior Regional Planner, Metropolitan Area Planning Council
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ABBREVIATIONS

CHAPA: Citizen’s Housing and Planning Association
EIA: Energy Information Administration
GIS: Geographic Information System
MAPC: Metropolitan Area Planning Council
MassDOT: Massachusetts Department of Transportation
MBTA: Massachusetts Bay Transportation Authority
MEPA: Massachusetts Environmental Policy Act
VMT: Vehicle Miles Traveled
Chapter 1: Introduction

1.1 Problem Statement

The rapid growth of Greenhouse Gas (GHG) emissions in the last few decades and the associated negative effects of global warming are causing increasing concern about sustainability. Along with urbanization and decentralization, the sustainability of metropolitan areas is considered one of the most significant challenges worldwide. Many countries around the world, especially developed countries, are facing problems of sustainable development in city and residential areas.

Recently, transportation-related challenges, such as congestion, GHG emissions, and excessive energy consumption, have been imposing tremendous pressure on the sustainability of metropolitan areas. Vehicular traffic accounts for one-third of all US GHG emissions, largely from passenger vehicles (EIA, 2008). The increasing car dependency generated by urban development has been seen as one of the major limitations to achieving sustainability in metropolitan areas (Bainster, 2000). On the other hand, the links between urban form and GHG emissions/transportation/travel behavior have been widely discussed on neighborhood and regional (metropolitan) scales (Donoso, 2006; Hankey and Marshall, 2010).

As a noticeable component of urban form, local residential developments may have great influence on local and regional sustainability. Efforts have been made to improve urban life and promote sustainability by advocating several mechanisms, such as transit-oriented development and mixed-use planning. However, because of the lack of
sufficient spatial data with fine resolution, few studies have addressed the impacts of individual residential development projects on local sustainability and the underlying implications for regional plans in detail. Therefore, the evaluation of a proposed development project relies instead on comprehensive post-empirical and quantitative analysis of the performance of new residential developments.

1.2 Research questions and hypotheses

In this thesis I propose to study several typical residential development projects with various types of background and surroundings and to examine their impacts on local sustainability in terms of transportation and environmental consequences.

My research questions are:

1) At the development level, what transport-related indicators should be estimated to represent the sustainability of the residential developments, and how is it possible to quantify the impacts of individual developments on local sustainability of the Metro Boston area?

2) What are the differences between developed areas (with new residential developments) and surrounding areas (without new residential developments)?

3) Do new residents have similar or different travel behavior compared to existing residents in the surrounding area?

4) How do the differences in transport-related consequence vary among similar developments with different surroundings, and among different developments with similar surroundings?
5) How do the characteristics of selected development projects and their neighboring areas determine such differences?

My preliminary hypotheses are:

1) According to the smart growth strategy, residential developments in more populated or developed areas will bring about a higher level of sustainability, e.g. generate less Vehicle Miles Traveled (VMT), than less dense areas or towns;

2) New residents will display travel behavior similar to that of existing residents in the nearby areas;

3) The impacts of selected developments are closely related to their own and their neighboring area’s demographic and built environment characteristics (e.g., population density and distance to major roads).

To test my hypothesis, I will examine the effects of selected residential development projects in terms of indicators of sustainability (e.g., VMT) and compare them with the surrounding area and the entire town. A comparison of the residential developments will reveal the ways in which built environment characteristics seem to determine the extent of this impact.

Such location-based performance or impact measures may assist in assessing potential consequences of proposed residential developments in terms of whether they are developed in the correct place and on the right scale, based on MetroFuture\(^1\) plan’s

\(^1\)MetroFuture plan is a vision of the Metro Boston area, where growth is focused in areas where it already exists and linked by an efficient transportation system. MAPC has created demographic and economic
projection. Meanwhile, quantifying the influence may enable decision-makers to compare alternative developments during the approval process of developments. The results may also facilitate the conversation between local government and regional institutions regarding the impacts of residential developments on local and regional sustainability.

1.3 Thesis structure

This thesis is organized into six chapters. The next chapter reviews the related literature to provide background information for the study.

Chapter three presents available data and the analytical framework for the study. Background information about the study area is introduced. It also discusses all data sources used for this study. The main analytical methodologies and process are also presented.

Chapter four focuses on transport-related impacts of the nine selected residential developments. Basic and background information about these developments is listed and analyzed. The approach to computing transport-related indicators – VMT per vehicle and VMT per household - is discussed. Comparisons of these indicators among development area, neighboring area, and the entire town demonstrate the transport-related consequences that are likely to be caused by each development project, whether new

projections of the region’s future; a set of 65 specific goals for the year 2030, as well as objectives and indicators we will use to measure progress toward achieving these goals (MAPC, 2009).
residents exhibit travel behavior similar to that of existing residents in the nearby areas, and how such consequences vary across different development projects.

Chapter five examines the possible underlying factors, especially built environment characteristics of development areas and neighboring area, that result in the different impacts of these developments. Density, land use, locational and other factors, such as job accessibility, are quantified and analyzed to discuss potential causality between the built environment and resultant travel demand of new residents.

Chapter six summarizes the main research findings, discusses the limitations and challenges of this study, and suggests future research.
Chapter 2: Literature Review

2.1 Urban sustainability and transport

Sustainability is a complex concept, encompassing economic, social, and environmental aspects. Housing developments are of great importance to sustainable development, but they are less frequently discussed because, traditionally, economic and social aspects always have taken precedence over environmental impacts and externalities (Tosics, 2004). Currently, sustainability has become a dominating principle in planning new residential areas. Urban sprawl is not considered a sustainable form of development due to its negative consequences, such as increased individual traffic and decreased environmental quality. Residential developments in different locations in metropolitan areas will, to some extent, result in changes in their local residents’ travel behavior, relocation of urban sources and activities, greater energy consumption, and other environmental effects on the neighborhood. Therefore, any urban residential development with sustainability in mind should aim to consume less land, generate fewer private car journeys, use existing urban resources, produce fewer negative effects on the surrounding environment, and conserve energy (Bromley et al., 2005; Boddy, 2007).

The measurement of sustainability has been widely discussed. Most researchers have considered sustainability in urban development using an integrative approach that addresses environmental, social, and economic objectives (Roseland, 2000). Social, economical, environmental, and cultural indicators have been compiled to characterize residential areas and to rank residential areas with respect to their sustainability. For example, to evaluate the sustainability of residential areas of Vilnius city, the principal
administrative center of Lithuania, 22 indices were taken from the RAIT survey (Market analysis and group of survey) in which the residents rated the desirability of the residential areas (Viteikiene & Zavadskas, 2007).

In recent years, the quality of life and sustainability in urban areas have been under increasing pressure due to the increased use of motor vehicles. In developed countries, particular attention is now being paid to the important roles played by current and emerging land use and transportation patterns in sustainable development (Deakin, 2001). There is also great concern for the adverse environmental and societal consequences generated by increasing traffic, such as congestion, traffic noise, air pollution, road safety, and energy depletion (Greene & Wegener, 1997; Banister, 2000).

Therefore, in some cases, sustainability only in terms of transport objective (such as travel behavior), rather than economic and social aspects, has been emphasized when exploring how the development of a new neighborhood area could proceed in a manner that fulfills sustainability criteria (Loukopoulos & Scholz, 2004). For example, residents’ modes of travel have been recognized as relevant to sustainability (Bromley et al., 2005). It has been argued that, in the Netherlands, if residents rely on walking or on public transport systems for most of their journeys, then they have a less adverse impact on the environment and their travel modes can be regarded as sustainable (Schwanen et al., 2002). Local sustainability seeks to establish less reliance on private car usage and fewer kilometers travelled by car, for example, by promoting compact residential development in areas well served by public transit. Although travel time, number of trips, distance
traveled, and modal choice are commonly used transport-related indicators, in this study, I chose only Vehicle Miles Traveled (VMT), a convenient measure of travel demand, as the indicator to represent the level of sustainability of development projects.

2.2 Characterizing a development project

At the housing development level, a household survey is the principal research method employed to evaluate a development project’s sustainability, particularly for residential development projects (Seo, 2002; Bromley et al., 2005). Such a survey is designed to extract information about income level, age structure, social class, car ownership, size of household, comparable distance from the residents’ modes of travel, and the location of employment and travel mode, which are recognized as relevant to sustainability. Evidence relating to the contribution of residential developments to sustainability in the city center was obtained by means of household surveys in two British cities (Bromley et al., 2005).

In Ontario, Hamilton-Wentworth's Sustainable Community Indicators Project attempted to measure progress toward community sustainability (Roseland, 2005). Decision-makers enlisted the participation of the community to obtain a final set of indicators for use. Such participatory methods have also been applied elsewhere in order to provide feedback to the planning organizations for strategic planning and implementation (Loukopoulos & Scholz, 2004).
However, the high monetary and time cost of household surveys tends to limit sample size, and privacy issues often bring about non-standardized and incomparable information, which cannot be applied across development projects. These concerns sometimes constrain the ability of survey-based studies to provide standard, accurate, and comparable data at the neighborhood and regional levels. Over the past several decades, many researchers have pioneered work on presenting a Geographic Information System (GIS)-based technique for representing built environment characteristics of metropolitan areas for urban sustainability studies. GIS data, especially spatially detailed data, has been widely used to characterize neighborhoods, urban forms, and regions (Crane & Crepeau, 1998; Diao, 2010). In this study, I take advantage of a newly available unique dataset, the odometer readings from annual safety inspections for all private passenger vehicles registered in Metro Boston. Spatially detailed datasets at the 250m*250m grid cell level are explored to develop an extensive analysis of new residential developments and their resultant vehicle usage.

2.3 Impact analysis of new residential development

Characterizing a development project itself is not sufficient to determine whether new residents have different travel behavior compared to existing residents or to capture the impacts of the development on local sustainability. Although few studies have been conducted to address the consequences of a development project on local sustainability quantitatively, we may obtain some insights from several comparable studies in regard to the economic or environmental impact of introducing other kinds of developments from local and regional perspectives.
Pollakowski et al. (2005) designed a methodology to identify the effects of introducing mixed-income, multi-family rental housing developments on surrounding single-family housing values. Several typical, large rental developments constructed between the mid-1980s and 2000 were selected within the Greater Boston region. The impact and control areas were identified to conduct a comparable analysis based on the hedonic model. The impact analysis of a specific development can be measured only if we can identify what would have occurred had the development never been constructed (Isserman & Merrifield, 1987).

Quasi-experimental control group methods have been applied to study the economic impacts of prison development on persistently poor rural areas (Farrigan & Glasmeier, 2002). A group of places where development did not occur was selected (non-randomly) by the authors as a control group for a place or places where development did occur.

Scenario analysis is another commonly used planning approach to address possible impacts of change. Under different urban growth scenarios, Hankey and Marshall (2010) studied the impact of urban form on future US passenger-vehicle GHG emissions. This method can deal with future uncertainty to some degree but has little to do with accuracy of predictions. It imagines only potential futures and identifies how local factors and driving forces can lead to such future approaches to dealing with uncertainty.
For this study, I develop a methodology combining the above-mentioned approaches to semi-quantitatively analyze the impacts of selected residential developments and how these impacts vary due to their different surrounding built environments. My methodology will be discussed in detail in Chapter 3.

2.4 Travel behavior and sustainable urban development

For the purpose of sustainability, urban planners and designers mostly incline to assert that development patterns, neighborhood features and densities affect how far, how often, and by what means residents travel. Numerous empirical studies (e.g. Kitamura et al. 1997) have demonstrated that people living in higher-density, mixed-use neighborhoods tend to generate fewer vehicle trips and shorter distances traveled compared to those living in lower-density suburban neighborhoods.

In one such study, Steiner (1994) explored several sets of literature to gain a better understanding of the connections between the residents in high-density residential areas, the land-use characteristics of the area, the residents’ transportation patterns, and the resultant environmental impacts. Researchers and decision-makers mostly recommend infill development, mixed land use, denser residential development, and proximity to public transit. They assume: 1) people living in denser residential areas will make fewer and shorter trips and prefer to walk or use public transit; 2) high-density residential areas have more mixed land uses and various destinations for residents; and 3) when people move to high-density areas, they will change their travel patterns.
A few researchers have addressed possible change in travel behavior as a result of a residential relocation. An empirical study (Krizek, 2003) proved that, within the Central Puget Sound region, Washington State residents would change their travel behavior when exposed to different built environments, different especially in accessibility. Bamberg (2006) argued that a residential relocation always provides the opportunity to investigate the role of changing context factors, along with a financial incentive intervention, as possible determinants of the observed change in travel mode choice. Stanbridge et al. (2004) also explored the influence of moving house on people’s travel behavior, and in particular mode choice, through qualitative interviews with people who recently moved house in the UK.

On the other hand, studies have also pointed out that such relocations or changes in context factors may not result in changes in travel behavior. A study claimed that, in the cities of Manchester and Glasgow, the regeneration of inner cities or city centers (i.e., attracting new residents back to town centers by developing new housing units in inner city areas) mostly attracted younger, white-collar workers with small household sizes (1~2 persons per household) who have different lifestyle preferences compared to older residents. They are likely to move again if they feel that the facilities in town centers cannot meet their needs as they get older (Seo, 2002). A study conducted in the San Francisco Bay Area in 1993 (Bagley & Mokhtarian, 2002) concluded that attitude, lifestyle, and other sociodemographic characteristics of residents had a greater impact on travel demand than location and neighborhood type of residential areas.
These inconsistent findings show that the effects of any specific neighborhood feature and development pattern on travel behavior are uncertain. It is also unsure how residents would change their behavior if they moved to a new place. The increasing popularity of the strategies of Smart Growth, Transit-Oriented Development, New Urbanism and Neotraditional Planning indicate the policy significance of this issue (Friedman et al., 1994; Crane, 1996; Crane & Crepeau, 1998). More in-depth studies should be conducted to address whether those strategies are effective for reducing automobile dependence in a specific metropolitan area. Each individual development should be evaluated separately to determine whether its net impact on auto use is positive or negative.
Chapter 3: Data and Methodology

3.1 Background

The Boston Metropolitan Area, which contains 101 cities and towns, provides the background for my study. Boston is the northernmost city of the largest megalopolis in the United States. It typifies dispersed American urban sprawl and exhibits a variety of built-environment and demographic characteristics, which makes it an appealing area for this study (see Figure 3-1).

Figure 3-1: The Boston Metropolitan Area
Although Boston’s historic growth pattern is compact and the use of transit is higher than the national standard, Metro Boston is “neither sustainable nor equitable, and will become less so” if recent land use patterns continue (MAPC, 2010, p8). Housing and jobs are dispersing across the region and growing at the highest rate in low-density suburbs with the highest VMT per capita, water, and energy consumption. Such trends have increased auto dependency, and developments now characterize a considerable amount of suburban growth. It still remains easier for developers to develop greenfields in suburban areas than to undertake urban infill, adaptive reuse, or densification in sensible locations.

The Metropolitan Area Planning Council (MAPC), a regional planning agency for the 101 cities and towns in Metro Boston, adopted the MetroFuture plan in 2008 to project long-rang regional growth and development. The analysis done during the MetroFuture planning process shows that housing and transportation costs, GHG emissions, health inequalities, racial and economic segregation, and concentrated poverty are all on the rise. The 101 cities and towns have different characteristics with diverse needs. The four general community types defined by the MetroFuture plan – inner core, regional urban centers, maturing suburbs, and developing suburbs – imply that a unique set of sustainability needs should be identified for each of the community types (see Figure 3-2).
The inner core includes high-density cities, such as Boston and Cambridge, as well as more residential-streetcar suburbs, such as Melrose. There is little available land for new developments, and most recent developments have occurred through infill and land recycling. More than one million jobs are located in the inner core area. Residents
of the cities typically live close to shops, jobs, and institutions but have limited access to green space. They can reach many places by walking, bicycling, and public transit.

**Regional urban centers** are a diverse group, comprising cities with high-density downtown cores, moderately dense residential neighborhoods, and (sometimes) lower-density single-family residential development. They include not only densely settled suburbs, such as Framingham, but also historic settlements like Gloucester. Such cities have more limited access to jobs and public transit than the inner core.

**Maturing suburbs** consist of homes for a burgeoning senior population. These communities are generally located along Route 128 or south of Boston. From most of them, it is fairly easy to reach the inner core and other job centers. However, a drive is required to go to other cities or towns. Some multifamily housing units are even in isolated locations far from shops, services, and jobs. The supply of affordable housing is generally limited. These communities are less diverse than the region overall and in need of more housing choices in transportation-efficient locations.

The region of **developing suburbs** is characterized by low-density and rapidly growing cities. These communities, such as Plymouth, are highly segregated, and most of buildings are single-family homes. As these communities are more remote from cities than other communities and lack substantial business or retail development, daily drives are frequently distant. They have abundant available land for development. However, current trends represent the greatest risk for unsustainable and equitable development.
Undoubtedly, individual development projects, especially residential developments, will collectively influence the implementation of the MetroFuture plan in each type of community and the sustainability of the entire Metro Boston area.

3.2 Data Sources

Geospatial data, including public datasets, plays an important role in this study by assisting in quantifying the built environment characteristics and patterns in and around the selected residential developments. This information allows us to explore how these patterns influence travel demand across the inner core to developing suburbs.

Metro Boston already has a robust framework for neighborhood and regional indicators. Spatially detailed GIS data collected by the state’s office of Geographic Information System (MassGIS), Registry of Motor Vehicles (RMV), and MAPC make location-based analysis on sustainability measures and impacts possible.

1. RMV dataset

This study uses a unique dataset, mandatory annual safety inspection records from the RMV, to estimate annual Vehicle Miles Traveled (VMT) by every private passenger vehicle registered in the Metro Boston area. These records include the odometer mileage readings reported to RMV and vehicle identification numbers (VIN) so that, using GIS tools, every vehicle can be associated with the street address of the vehicle owner and geocoded to place of residence. Overall, approximately 3.7 million private passenger vehicles are included in this dataset, around 85% of which have credible odometer
readings. Availability of VMT data enables us to evaluate impacts of an individual development on local sustainability to some extent.

2. MassGIS datasets

This study also benefits from built-environment data with exceptional spatial detail, primarily from MassGIS. MassGIS collects a great deal of data from many resources, including business locations, institutional destination locations such as schools, road networks, population and census household data. The spatial unit used in this study, a 250m*250m grid cell layer, was also developed by MassGIS. The grid cell approach enables many operations to be performed on grids with little computational effort. The main datasets used in this study and provided by MassGIS include:

- 2000 and 2010 U.S. Census data, especially population data;
- 1999 and 2005 land use data;
- 2008 Massachusetts Department of Transportation (MassDOT) roads data.

3. Development datasets

The newly updated development project dataset provided by MAPC includes some developments built since the 1990s and their spatial and demographic information, such as location, area, new housing units, and development type. Although related information has not been completely provided, this dataset still greatly facilitates this study by providing a large development project pool from which several suitable developments can be selected. Meanwhile, the Massachusetts Environmental Policy Act (MEPA) Project Tracking System database records environmental impacts of
development projects submitted for MEPA review, which also offers a reference for housing development candidates.

Avalon communities (apartment communities developed by AvalonBay Communities Inc.\(^2\)), which can be identified through aerial photographs, introduce additional representative housing developments in the Metro Boston area for this study.

4. Secondary data

MIT course 11.521 (Spatial Database Management and Advanced Geographic Information Systems) in spring 2011 assigned block level 2000 and 2010 census household and population data to 250m*250m grid cells based on residential land use, which greatly assists this study (Jacobi et al., 2011).

This study also takes advantage of 27 built environment variables computed by a PhD student Mi Diao at the grid cell level (Diao, 2010). I will choose several variables, such as job accessibility and distance to public transit, to represent the built environment characteristics of surrounding areas for each residential development.

\(^2\)AvalonBay Communities Inc., incorporated in 1993, is one of the nation's leading Real Estate Investment Trusts (REITs), developing, redeveloping, acquiring, and managing apartment communities all across the United States. It aims to develop luxury rental apartment communities on the sites that are within easy reach of employment hubs, transportation, shopping and entertainment.
3.3 Methodology and Research Design

The ultimate goal of this study is to develop an appropriate approach for examining the impacts of residential developments on local sustainability in the Metro Boston area and how and why such impacts vary across different types of communities.

3.3.1 Project selection

The first step in this study is the selection of typical residential development projects. To find appropriate residential developments, I explored the abovementioned datasets – the MAPC development project dataset, the MEPA project database, and the Avalon communities.

First, I chose to limit selection to residential development projects completed by 2005. Such projects had been fully developed and occupied before the time when the RMV data was available. Therefore, I can calculate VMT indicators as a possible way to quantify local sustainability. I searched in the MAPC development dataset for projects that were finished before 2005 and classified as residential developments, or 40B3, or that could be recognized on the MassGIS 2008 color aerial photo as a residential development project.

Second, according to the MetroFuture plan for the Metro Boston area, I believe it is important to select at least one project of each community type in Metro Boston (inner

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3 Chapter 40B, enacted through the Comprehensive Permit Law and Anti-Snob Zoning Act, is a Massachusetts statute that enables developers to obtain state-authorized comprehensive permits in municipalities that are not in compliance with state affordability criteria: If less than ten percent of a municipality’s housing stock is defined as affordable, developers with comprehensive permits can build developments that override local zoning regulations (CHAPA, 2007).
core, regional urban centers, maturing suburbs, and developing suburbs). This way, I can observe how the impacts of those developments in terms of VMT vary across different community types.

Next, I investigated the MEPA dataset and the Avalon communities across the Metro Boston area. Aided by the MassGIS 2008 color aerial photo, I chose two more Avalon developments to complement the resulting selections from the MAPC development dataset.

Finally, based on the available development datasets, I selected nine development projects to represent typical and remarkable residential developments in Metro Boston area. I had expected that at least two projects could be chosen for each community type, but ultimately only one project was selected to represent the inner core community owing to the lack of developable land in the inner core cities.

Additionally, I manually traced the boundaries of the nine residential developments using aerial photographs in order to obtain a better sense of the developments themselves and their neighboring areas. Detailed information about the nine developments and their surrounding areas is provided in Chapter 4.

3.3.2 Identification of neighboring areas

The neighboring area for each development is intended to represent the neighborhood within which the development is located. To identify an appropriate neighboring area for each development, I overlaid the RMV data layers and the MAPC development data
layers with the MassGIS 2008 color aerial photo. My objective was to find a buffer area, with a certain distance from the edge of each development, which could capture the major neighborhood characteristics of surrounding areas, have a sufficient numbers of RMV readings, and not embrace other new residential developments before 2010. Because I will use some indicators computed from 2010 census data, such as population density, to characterize the neighboring area, it is desirable to exclude potential influence of other new residential developments completed by 2010.

Based on these criteria, I observed that a 1000-meter buffer area was an appropriate neighboring area. However, for one development, Endicott Green in Danvers, another 50-acre residential development, Avalon Danvers, was completed in 2007 and is located within its 1000-meter buffer. Consequently, I choose 750 meters as the buffer distance, which is also the distance of three 250m-grid cells. Although there are still other developments within 750m buffer areas, none of them is a residential development completed by 2010. Some of them are commercial or institutional developments and some are residential developments currently under construction or in planning.

3.3.3 Impacts analysis
Travel patterns (based on car travel) or travel behavior of local residents resulting from new residential developments can reflect the sustainability of a certain area to a great extent. As a result, I chose two transport-related indicators, VMT per vehicle and VMT per household, to quantify the impacts of these developments on local sustainability.
A 750-meter buffer area was generated for each selected residential project as a comparable or control area. Meanwhile, I computed the two indicators at the town level to provide the background information for a broader area. Comparison of the selected developments will reveal whether new residents have same travel behavior as existing residents, what transport-related impacts are caused by the new residential developments, and how and why such impacts differ across the developments.

3.3.4 Potential factors resulting in variation of impacts

To explain why the impacts of these residential developments vary across space, it is necessary to identify the built environment indicators that are most likely to influence travel behavior or local residents in order to characterize selected developments and their surrounding areas. Based a preliminary analysis, I chose population density, road density, land-use mix, job accessibility, distance to public transit, distance to major roads, job accessibility and other potential factors that may account for differences between the impacts of each development.
Chapter 4: Transport-related Impacts of New Residential Developments

The research methodology employed here is designed to examine the impacts of new residential developments on local sustainability. Transport-related indicators - VMT per vehicle and VMT per household – are chosen to represent the level of sustainability and to explore how the travel behavior of new residents differs from that of existing residents.

4.1 Selected Developments

Based on the development selection process described in Chapter 3, nine residential developments in Metro Boston area are identified for this study. As can be seen in Figure 4-1, the nine developments in the study are dispersed throughout the Metro Boston metropolitan area. Gloucester is northeast of the city at the northeastern end of Route 128. Both Peabody and Danvers are divided by Interstate 95 and Route 128, the intersection of which is located in Peabody. Bedford lies northwest along Route 3 and Route 2 bisects Concord. Melrose is located in the north of Boston along Route 1. Westwood is along the southwestern section of Interstate 95 and Walpole lies southwest along Route 1. Finally, the southern end of Route 3 passes through Plymouth, a town further south of Boston.
Figure 4-1: Locations and Aerial Photos of Selected Residential Developments
### Table 4-1: Basic Characteristics for Nine Selected Developments

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Development Type or Zoning</th>
<th>Municipality</th>
<th>Corridor</th>
<th>Community Type</th>
<th>Computed Area (acre)</th>
<th>Total Housing Unit</th>
<th>Year Completed</th>
<th>Other Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP</td>
<td>40B Large Multi-family Housing</td>
<td>Walpole</td>
<td>Southwest</td>
<td>Developing Suburbs</td>
<td>21.329</td>
<td>300</td>
<td>2004</td>
<td></td>
</tr>
<tr>
<td>Avalon at the Pinehills</td>
<td>Avalon Community</td>
<td>Plymouth</td>
<td>South</td>
<td>Developing Suburbs</td>
<td>5.661</td>
<td>before 2005</td>
<td>One Avalon Way, Plymouth, MA</td>
<td></td>
</tr>
<tr>
<td>Nordic Way Subdivision</td>
<td>Single-family Housing</td>
<td>Melrose</td>
<td>North</td>
<td>Inner Core</td>
<td>5.036</td>
<td>7</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Endicott Green</td>
<td>40B Large Multi-family Housing</td>
<td>Danvers</td>
<td>Northeast</td>
<td>Maturing Suburbs</td>
<td>12.898</td>
<td>258</td>
<td>2004</td>
<td>180 Newbury Street - completed and fully occupied</td>
</tr>
<tr>
<td>Avalon at Great Meadows</td>
<td>40B Avalon Community Small Multi-family Housing</td>
<td>Bedford</td>
<td>Northwest</td>
<td>Maturing Suburbs</td>
<td>9.512</td>
<td>139</td>
<td>2005</td>
<td>Now known as Avalon at Bedford Center</td>
</tr>
<tr>
<td>Highland Glen Expansion</td>
<td>40B Large Multi-family Housing</td>
<td>Westwood</td>
<td>Southwest</td>
<td>Maturing Suburbs</td>
<td>12.289</td>
<td>104</td>
<td>2003</td>
<td>Number of people over 55: 102</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Abbott Lane</td>
<td>40B Large Multi-family Housing</td>
<td>Concord</td>
<td>Northwest</td>
<td>Maturing Suburbs</td>
<td>6.472</td>
<td>42</td>
<td>2003</td>
<td>2003 - 40B approved for 42 units of rental housing</td>
</tr>
<tr>
<td>Magnolia Estates</td>
<td>Conventional Subdivision Single-family Housing</td>
<td>Gloucester</td>
<td>Northeast</td>
<td>Regional Urban Centers</td>
<td>17.092</td>
<td>20</td>
<td>2005</td>
<td>All lots are built.</td>
</tr>
<tr>
<td>Avalon Essex</td>
<td>Avalon Community</td>
<td>Peabody</td>
<td>Northeast</td>
<td>Regional Urban Centers</td>
<td>11.377</td>
<td>before 2005</td>
<td>One Avalon Dr, Peabody, MA</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4-1 also shows aerial photographs of the selected developments. As we can see from the aerial photos, all the nine developments have apparent building patterns that distinguish them from their surrounding areas in spite of their differing sizes ranging from 5 acres to 21 acres. Although all the developments appear quite similar, they are structurally, functionally, and locationally different from each other.

Table 4-1 details the characteristics of each project, including its development type, location, community type, size, total housing units (if available), year completed, and other related information. All areas are computed from the boundaries I manually traced (see Figure 4-1) and some of them are different from those recorded in the MAPC development dataset. This difference may be because some claimed plots have not been developed or were developed into open space. For this study, it is more reasonable to use an approximate but visible boundary for each development project than a nominal boundary.

Among the nine projects, five of them are 40B projects with 40 to 300 new housing units, a certain percentage of which are affordable housing units. The five 40B developments are located in the maturing suburb or the developing suburban area outside of the semicircle of Route 128. “Small multi-family housing” means multi-family housing up to five units, townhouses, and attached single-family housing, while “large multi-family housing” indicates units in structures with six or more units.
The two single-family housing developments, in Melrose and Gloucester, lie in an inner core and a regional urban center, respectively. They contain only a small number of housing units, although their neighboring areas are densely populated.

The two Avalon communities, in Peabody and Plymouth, are luxury rental housing developed by AvalonBay Communities Inc. As they are not included in the MAPC development dataset, detailed information regarding number of units and completion time is lacking. Since they can be identified on the MassGIS 2005 color aerial photo and do not appear in the 2000 aerial photo, we may deduce that they were completed before 2005. In addition, Avalon communities are primarily developed for renting; therefore, most of the occupants of the Avalon developments are renters rather than owners. They usually have mixed building types (e.g. mixture of townhouses and mid-rise apartment buildings) to accommodate varieties of target customers (see Figure 4-2).

**Figure 4-2: Picture of Avalon Communities in Peabody and Plymouth**

Source: www.avaloncommunities.com
For each development, its surrounding area (750m buffer area) also has various built environment characteristics, which are observable through aerial photographs with high resolution (see Appendix 1). The majority of the selected developments are either sited at the edges of local existing residential areas or cut off from the nearest communities by a certain amount of open space or major roads. Only the developments in Danvers and Peabody appear to be integrated into local residential neighborhoods.

4.2 VMT Indicators Computation

I picked out all RMV odometer-reading records within the nine towns in which the selected nine developments are located: 149,299 readings are included, recorded from 1/7/2006 to 5/31/2008, with estimated annual miles ranging from 0 to 99,883 miles. Records with RMV readings less than 1000 miles and greater than 300,000 miles per year are questionable and are hard to interpret. Consequently, I manually discarded the records with RMV readings less than 100 miles, and assigned 1000 miles to the vehicles with readings less than 1000 miles and 300,000 miles to the vehicles with readings greater than 300,000 miles. As a result, 500 records were removed from the RMV dataset for the nine towns.

VMT is a widely used indicator in transport-related research. For this study, to determine appropriate transport-related indicators, I estimated several VMT-related indicators through various approaches by using existing RMV readings. Finally, I chose the following methods to calculate two VMT indicators – VMT per vehicle and VMT per
household – for the selected developments, neighboring areas and towns, to represent the level of sustainability of each development.

4.2.1 VMT per vehicle

Diao (2010) computed VMT per vehicle for the entire Metro Boston area at a 250m grid cell level. He also used a 9-grid cell neighborhood average to smooth the spatial distribution of VMT per vehicle. However, for this study, I focus on the residential developments whose smallest area is only around 5 acres, smaller than one grid cell. To estimate VMT per vehicle for each development more accurately, I searched for RMV readings for vehicles exactly located within the boundaries of all selected developments and calculated the corresponding average VMT for each development. Figure 4-3 shows examples of how vehicles with RMV readings are distributed within each development area.

The statistics in Table 4-2 indicate how many cars with RMV readings are included in each development area, its neighboring area, and the town in which it is located. The car density for each area also gives a general idea about vehicle usage in each area. Although the RMV dataset does not contain all vehicles in the Metro Boston area, the numbers in the table appear relatively plausible considering the size, development type, and location of each development. The examples in Figure 4-3 represent the developments with the fewest cars (Melrose), the most cars (Peabody), and the greatest density of cars (Plymouth).
Table 4-2: Number of Vehicles with RMV Readings for Each Area

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>Devlp Area</th>
<th>Neighbor Area (750m)</th>
<th>Background Info (Town)</th>
<th>Devlp Car Density (per acre)</th>
<th>Neighbor Car Density (per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>44</td>
<td>528</td>
<td>15221</td>
<td>2.06</td>
<td>0.74</td>
</tr>
<tr>
<td>Avalon at the Pinehills, Plymouth</td>
<td>Developing Suburbs</td>
<td>102</td>
<td>80</td>
<td>35463</td>
<td>18.02</td>
<td>0.14</td>
</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>6</td>
<td>1120</td>
<td>15760</td>
<td>1.19</td>
<td>2.07</td>
</tr>
<tr>
<td>Endicott Green, Danvers, Bedford</td>
<td>Maturing Suburbs</td>
<td>19</td>
<td>963</td>
<td>17293</td>
<td>1.47</td>
<td>1.59</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>36</td>
<td>579</td>
<td>8752</td>
<td>3.78</td>
<td>0.93</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>43</td>
<td>1261</td>
<td>9225</td>
<td>3.50</td>
<td>2.08</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>34</td>
<td>541</td>
<td>10632</td>
<td>5.25</td>
<td>0.92</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>39</td>
<td>366</td>
<td>4823</td>
<td>2.28</td>
<td>0.56</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>124</td>
<td>1454</td>
<td>31630</td>
<td>10.90</td>
<td>2.44</td>
</tr>
</tbody>
</table>

Figure 4-3: Examples of RMV Readings Distribution within Development Areas (Blue dots represent the locations of RMV odometer readings.)
However, the sampling problem seems to be very severe for several selected developments if comparing the number of RMV readings in Table 4-2 and the total housing units listed in Table 4-1. For instance, the Danvers project proposes to develop 258 housing units, which should have been completed in 2004; however, only 19 RMV readings are identified in the Danvers development area. The Walpole development has almost same problem: only 44 vehicles with good RMV readings are recognized for 300 housing units in this development project. Only the Gloucester project appears to own almost twice as many cars as housing units.

Although the distribution of RMV readings does not completely reflect the real car distribution for each development area, we still can observe some general trends. The car densities of most developments are higher than those of their surrounding areas, except for the developments in Melrose and Danvers—the two projects located in more populated areas. More vehicles are registered in Plymouth’s development than in its neighboring area. It is worth pointing out that the two Avalon communities encompass more vehicles than other developments and have higher car densities as well. However, the neighboring area of the Avalon community in Plymouth has the lowest car density. It seems that this community is an isolated development project in a suburban area.

For the surrounding areas (750-meter buffer area) and the towns where the developments are sited, I tested several approaches to estimate the VMT per vehicle for those areas. Finally, I took advantage of the VMT per vehicle calculated by Diao (2010) for the Metro Boston area because I believe that the smoothed VMT per vehicle better
reflects the conditions of car usage in the neighboring and background areas. The average of VMT per vehicle in all grid cells intersecting with the 750-meter buffer areas and the town boundaries are computed for each project to compare the transport-related consequences of these residential developments and to assess whether new residents behave similarly to existing residents.

4.2.2 VMT per household

It is more challenging to estimate VMT per household than VMT per vehicle. This is because VMT per vehicle is estimated directly from odometer readings, which are more reliable, stable, and objective. VMT per household computation is determined not only by odometer readings but also by the estimation of household numbers. The census dataset records the number of households at the census block group level, which is the smallest geographic entity for which the decennial census tabulates and publishes sample data. Usually, one block group is much larger than the grid cell I use here, as well as the developments in this study. It is an arduous task to allocate census block level household numbers to a smaller spatial unit. MassGIS did allocate 2000 census data to the 250m grid cells, but this data is outdated. There are few households allocated to some development areas, such as zero households in the Plymouth one, which was definitely the case in 2000 (see Appendix 2).

Fortunately, instructed by Professor Joseph Ferreira, the students in MIT’s course 11.521 (Jacobi et al., 2011) tried to allocate the newest census data, 2010 population and household survey data, to the 250m grid cells based on the residential land use map.
produced by MassGIS. Although it is a tentative allocation of 2010 census block group population and household, the results provide the newest dataset with respect to the distribution of population and household in Metro Boston area at the 250m grid cell level.

**Figure 4-4: Examples of Overlaying Development Areas with Grid Cells**

To calculate the household number for each development, I overlaid the developments boundaries and the 250m grid cells. Figure 4-4 displays examples of how the development area overlaps with the grid cells. Since our selected developments are relatively small comparing to the grid cell, I did not compute the household numbers simply by summing the household numbers in the grid cells intersecting with the development areas. I calculated the percentage of development areas in each grid cell and multiplied that percentage by the household number in each grid cell to get the proportional household number for each development area. The proportional household numbers were added up to obtain the total household number for each development (Table 4-3).
Table 4-3: Resulting Number of Household for Each Development

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>No. of Grid Cells</th>
<th>No. of Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>7</td>
<td>136.79</td>
</tr>
<tr>
<td>Avalon at the Pinehills, Plymouth</td>
<td>Developing Suburbs</td>
<td>2</td>
<td>21.93</td>
</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>4</td>
<td>4.79</td>
</tr>
<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>5</td>
<td>12.41</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>4</td>
<td>8.07</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>3</td>
<td>60.19</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>4</td>
<td>11.79</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>4</td>
<td>11.61</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>3</td>
<td>94.66</td>
</tr>
</tbody>
</table>

I did not use the household numbers listed in Table 4-1 because: 1) we do not have detailed household numbers for the two Avalon projects; 2) we are not sure about the occupancy rate of each development, which is crucial to estimating exact household numbers. Even if the estimated household number for each development is smaller than what is reported, for the purpose of comparison, it is better use the computed household numbers to maintain the consistency of data sources.

To estimate VMT per household for each development, I also summed the RMV odometer readings in each development area and divided the total by the household number I calculated. The results will be analyzed in the following section.
To compute VMT per household for the neighboring areas and the towns, I again applied the data on the grid cell level. I searched for all grid cells that intersect with each development area. The total VMT in each grid cell computed by Diao was divided by the household number allocated by the students in course 11.521. To avoid abnormally large numbers caused by small household numbers, I omitted the grid cells that are estimated to have less than one household. Through this process, the VMT per household computed for the surrounding areas and the towns was made more stable and reasonable. The results will be presented in the following section.

4.3 Transport-related Impacts

I mapped the two VMT indicators – VMT per vehicle and VMT per household – for each development project (Figure 4-5). As revealed by the map, most of the numbers seem plausible in spite of some surprising results. Generally speaking, VMT per vehicle is a reasonable and stable indicator. The suburban projects further away from city centers have higher VMT per vehicle than those closer to city centers.
Surprisingly, the development in Melrose, located in the inner core, also has a relatively high VMT per vehicle. On careful examination of this development, we perceive that it is a single-family housing development located in a relatively remote area of the inner core. Its residents have to drive for most of their activities due to the isolation created by a large amount of open space. The travel distances may be shorter
than those in suburban areas, but the travel frequency may be higher, which offsets the advantage of lying close to city centers.

Another exception is the development in Westwood. Approximate 6,700 miles per vehicle per year sounds implausible for residents in a suburban area. Forty-three vehicles are registered in the development area, but there are more than 100 housing units. Scrutiny reveals that its residents are mostly elderly people (as reported in MAPC dataset, 102 people over 55 years old) whose travel demand is much less than that of younger residents.

In terms of VMT per household, in general, it is less stable and reliable than VMT per vehicle, but it is still valuable to look into this indicator. Empirical studies have confirmed that sometimes VMT per household can better reflect residents’ travel demand in the suburban areas given that families there are more likely to have more than one private car, resulting in lower VMT per vehicle but higher VMT per household.

VMT per household has larger variation among the nine selected developments, ranging from 4,700 miles per household per year to 81,000 miles per household per year. The development in Plymouth, the town furthest away from the city of Boston, has the highest VMT per household, which is reasonable though the number may be exaggerated by the underestimated household number. The same problem occurs in the developments in Bedford and Gloucester. On the other hand, if the low VMT per household in Westwood, a town in a maturing suburb, can be explained by the residence of a large
number of elderly people, the unexpectedly low VMT per household for the development in Walpole, a town in a developing suburb, indicates that the number of cars was improperly counted or the development was not fully occupied when the RMV readings were collected.

As a result, even if VMT per household is generally higher than VMT per vehicle for the other seven developments (except Westwood and Walpole), it cannot be inferred that on average the households residing in the seven developments own more than one car. Therefore, at the development level, VMT per household is a controversial indicator to represent travel behavior of local residents, unless the exact numbers pertaining to households and car ownership are known.

For the purpose of comparison, VMT per vehicle and VMT per household of the neighboring areas and the towns were also calculated through the above-mentioned approaches. The results were grouped under the community types, and comparisons were conducted within and between different types. In this way, we can obtain ideas about the different consequences for similar developments with different surroundings or different developments with similar surroundings. Moreover, the resulting VMT indicators can aid us in understanding whether new residents tend to travel in a manner similar to that of existing residents.
Figure 4-6: Comparison of VMT per Vehicle

Developing Suburbs
- Devlp Area
- Neighbor Area (750m)
- Background Info (Town)

Regional Urban Centers
- Devlp Area
- Neighbor Area (750m)
- Background Info (Town)

Inner Core
- Devlp Area
- Neighbor Area (750m)
- Background Info (Town)

Maturing Suburbs
- Devlp Area
- Neighbor Area (750m)
- Background Info (Town)
As shown in Figure 4-6, there are certain differences between VMT per vehicle in some development areas and in their surrounding areas. Obviously, the similar developments (40Bs or Avalon communities) in the developing suburbs have higher VMTs per vehicle than those in the maturing suburbs or the regional urban centers. Similarly, the differences between the development areas and their neighboring areas are larger in the developing suburbs than in the maturing suburbs or the regional urban centers.

As 40B developments, the Walpole and the Concord developments generate higher VMT per vehicle than their surrounding areas. The Bedford development is a 40B small multi-family housing development, producing almost the same VMT per vehicle as its neighboring area. The Danvers and Westwood developments yield lower VMT per vehicle than their adjacent areas and their towns. Aside from the reasons that the Danvers development is more integrated into its neighborhood and the residents of the Westwood development are mostly elderly people, there should be other influential factors, special built environment characteristics that have impacts on the resultant VMT per vehicle. We will explore this issue in Chapter 5. The residents of 40B developments seem to have different travel preferences than the existing residents. However, the surrounding areas of all 40B developments have slightly higher VMTs per vehicle than their towns.

Being an Avalon community, the Plymouth development apparently generates a much higher VMT per vehicle than the Peabody and Bedford developments. The
difference in VMT per vehicle between the development area and its nearby area in Plymouth, a town in a developing suburb, is also much higher than the other two Avalon communities, located in a regional urban center and a maturing suburb. Like the Bedford development, the Peabody one also has almost the same VMT per vehicle as its neighboring area. It appears that new residents of Avalon developments in more populated areas have travel demands or patterns similar to those of their neighbors. Occupants residing in the more isolated Avalon community seem to drive more than the original residents.

As a single-family housing development, the Gloucester development has a higher VMT per vehicle than the Peabody development in the regional urban center. Its VMT per vehicle is even higher than those of 40B developments in the maturing suburbs. It also generates higher VMT per vehicle than its neighboring area. The Melrose development, another single-family housing development located in the inner core, generates a much higher VMT per vehicle than its neighboring area, although its surrounding area has almost the same VMT per vehicle as that of the town. It seems that the single-family housing development, especially one cut off from background dense residential areas, brings about a more negative transport-related impact on local sustainability. Therefore, it is worthwhile to delve into the built environment characteristics of the development areas and their neighboring areas, to better identify the underlying factors that result in such differences.
Owing to relative instability and inaccuracy of estimation on VMT per household, compared to VMT per vehicle, some abnormal numbers significantly affect the comparison between the developments from VMT per household perspective. Even though the absolute numbers in Figure 4-7 are less likely to be meaningful than VMT per vehicle, we can still discover some general trends.

The lower VMT per household for the Walpole, Peabody and Westwood developments compared to their surrounding areas implies that the densities of these developments are higher than those of their surrounding areas (i.e. more households are located in the development areas). This suggestion will be tested through the analysis in the next chapter.

It is also worth pointing out that VMT per household is still a reliable indicator on the neighborhood and regional scale. From Figure 4-7, we can see that the VMT per household for the neighboring areas in the developing suburbs, the regional urban centers, and the inner core is generally higher (or slightly higher) than the VMT at the town level. In contrast, in the maturing suburbs, VMT per household of the adjacent areas is usually lower than at the town level. We may draw the inference that all 40B developments in the maturing suburbs tend to choose a relatively denser neighborhood in the town in which to build.
Figure 4-7: Comparison of VMT per Household
Table 4-4 quantitatively summarizes the impacts of each development in terms of transport-related consequences. The percentages in the table were calculated by dividing the difference in VMT per vehicle or VMT per household between the development area and the neighboring area by VMT per vehicle or VMT per household in the neighboring area. The same computation was conducted to arrive at the percentages for the difference with respect to the entire town. The positive percentages indicate negative impacts and the negative percentages stand for positive impacts on local sustainability from the transport-related perspective. The smaller the absolute percentages, the closer the resulting VMT indicators of the selected developments are to those of the neighboring areas or the towns.

In general, the 40B developments in Danvers and Westwood can be considered more sustainable developments than the others from a transport-related perspective. Their sustainability is represented by shorter travel distance, fewer cars, or denser development. Certainly, the elderly people living in the Westwood development tend to travel less than younger people, which contributes to the development’s positive impacts on sustainability. This implies that 40B developments or similar large multi-family housing developments in the maturing suburbs may be able to generate less travel demand than the neighboring areas, even other areas closer to city centers if appropriately positioned and operated. Under such circumstances, the new residents may not necessarily travel as much as their neighbors.
Table 4-4: Summary of Comparison

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>VMT Indicators</th>
<th>Devlp Area</th>
<th>Neighbor Area (750m)</th>
<th>Background (Town)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>VMT/Vin</td>
<td>14532</td>
<td>13260</td>
<td>9.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>4674</td>
<td>31121</td>
<td>-85.0%</td>
</tr>
<tr>
<td>Avalon at the Pinehills, Plymouth</td>
<td>Developing Suburbs</td>
<td>VMT/Vin</td>
<td>17445</td>
<td>15022</td>
<td>16.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>81126</td>
<td>48109</td>
<td>68.6%</td>
</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>VMT/Vin</td>
<td>14511</td>
<td>10009</td>
<td>45.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>18163</td>
<td>21989</td>
<td>-17.4%</td>
</tr>
<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>10005</td>
<td>11234</td>
<td>-10.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>15319</td>
<td>22670</td>
<td>-32.4%</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>11490</td>
<td>11162</td>
<td>2.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>51262</td>
<td>21677</td>
<td>136.5%</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>6736</td>
<td>11997</td>
<td>-43.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>4812</td>
<td>21464</td>
<td>-77.6%</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>12646</td>
<td>11261</td>
<td>12.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>36467</td>
<td>25080</td>
<td>45.4%</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>VMT/Vin</td>
<td>13435</td>
<td>12530</td>
<td>7.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>45133</td>
<td>24431</td>
<td>84.7%</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>VMT/Vin</td>
<td>10235</td>
<td>10215</td>
<td>0.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VMT/HH</td>
<td>13407</td>
<td>34749</td>
<td>-61.4%</td>
</tr>
</tbody>
</table>

The Avalon communities in Peabody and Bedford can be regarded as good examples, confirming my hypothesis that new residents would exhibit travel behavior similar to that of nearby existing residents (i.e. VMT per vehicle similar to the neighboring areas and the towns) but only under certain conditions. Either positive or
negative impacts in terms of VMT per household result only from the effects of different densities. The Bedford development also exhibits a slightly higher VMT per vehicle than the Peabody one due to their different geographic locations and community types.

All other developments seem to have greater travel demand, which is deemed to be a less sustainable lifestyle. Two single-family housing developments, whether they are located in the inner core or the regional urban centers, all have negative impacts on local sustainability by generating more traffic on the roads. The residents of both developments in the developing suburbs (Plymouth and Walpole) tend to travel longer than their neighbors, especially the Plymouth development, another Avalon community. Due to the higher density, the Walpole development appears to have fewer VMT per household; however, the longer distance traveled by new residents underscores the significance of new residential development locations and the built environment characteristics of their surrounding areas.

We can preliminarily conclude that new residential developments do not always have negative impacts on local sustainability from a transport-related perspective. New residents also do not always have travel patterns similar to those of existing residents in the nearby areas. New residents’ behaviors are greatly influenced by the built environment characteristics of neighboring areas, such as density and geographic location. They are also affected by many other factors, such as the development type, even though the new residential developments are situated in the same type of communities.
Chapter 5: Built Environment Characteristics of Development Projects

Empirical studies have proven that built environment characteristics of residential areas influence local sustainability to some extent from a transport-related point of view, if other elements are not taken into consideration; for instance, attitudinal, lifestyle, and sociodemographic factors (Bagley and Mokhtarian, 2002; Diao, 2010). From a design perspective, seven concepts have been identified for sustainable urban form: compactness, sustainable transport, density, mixed land uses, diversity, passive solar design, and greening (Jabareen, 2006).

Based on available spatially detailed data, this chapter examines the possible underlying factors, especially the built environment characteristics of development and neighboring areas, which have unique impacts on these developments. Density, land use, location, and other factors, such as job accessibility, are quantified and analyzed in order to discuss potential relationship between the built environment and resultant travel demands of new residents.

5.1 Density

Although it is a well accepted argument that the volume of travel and car usage decreases with population density, it is not clear whether it applies to the case of individual
developments. This section explores two density-related indicators—population density and road density—to demonstrate how density relates to travel demand at the residential development level.

### 5.1.1 Population density

Calculating population density at a fine resolution is challenging, as population data is tabulated and published at the census group level. As mentioned in Chapter 4, MassGIS allocated the 2000 population data to the 250m grid cells. Students in MIT’s course 11.521 employed the same approach for the 2010 population and household data. For this study, I calculated the 2010 population for each development using the same method for computing household data in Chapter 4 (see Appendix 3). The population was divided by the computed area for each development to obtain the population density. For the neighboring areas (750m buffer area) and towns, I added the allocated populations in all grid cells that intersected with the neighboring areas and the town boundaries, and then divided the sum by the total areas in corresponding grid cells. The same method was applied to calculate the 2000 population density for the development areas, their neighboring areas, and their towns. In addition, I also calculated population density for each area by excluding non-residential grid cells (i.e., no population allocated to those grid cells). The resulting numbers are listed in Table 5-1.
### Table 5-1: Total Population Density VS Population Density of Residential Areas in 2000 and 2010

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>Development Area</th>
<th>Neighbor Area</th>
<th>Background (Town)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>3532.98</td>
<td>96.30</td>
<td>36.69</td>
</tr>
<tr>
<td>Avalon at the Pinehills, Plymouth</td>
<td>Developing Suburbs</td>
<td>1872.77</td>
<td>0.00</td>
<td>N/A</td>
</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>650.65</td>
<td>596.44</td>
<td>1.09</td>
</tr>
<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>545.15</td>
<td>338.49</td>
<td>1.61</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>519.85</td>
<td>249.33</td>
<td>2.08</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>1830.90</td>
<td>949.33</td>
<td>1.93</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>1027.36</td>
<td>417.33</td>
<td>2.46</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>485.29</td>
<td>237.78</td>
<td>2.04</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>3965.24</td>
<td>1223.11</td>
<td>3.24</td>
</tr>
</tbody>
</table>

#### Total Population Density (including Non-residential Area)

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>Development Area</th>
<th>Neighbor Area</th>
<th>Background (Town)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>3532.98</td>
<td>82.54</td>
<td>42.80</td>
</tr>
<tr>
<td>Avalon at the Pinehills, Plymouth</td>
<td>Developing Suburbs</td>
<td>1872.77</td>
<td>0.00</td>
<td>N/A</td>
</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>650.65</td>
<td>596.44</td>
<td>1.09</td>
</tr>
<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>545.15</td>
<td>338.49</td>
<td>1.61</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>519.85</td>
<td>249.33</td>
<td>2.08</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>1830.90</td>
<td>949.33</td>
<td>1.93</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>1027.36</td>
<td>417.33</td>
<td>2.46</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>485.29</td>
<td>237.78</td>
<td>2.04</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>3965.24</td>
<td>1223.11</td>
<td>3.24</td>
</tr>
</tbody>
</table>
The table not only shows how population has grown in the development areas, their neighboring areas, and their towns over the past 10 years; it also illustrates how the neighborhoods and towns are populated. The significant difference between the total population density and the population density without non-residential areas indicates either that people are concentrated in these areas, or that a large amount of land in these areas has not been developed. As seen in Table 5-1, the populations in the nine development areas have increased dramatically due to these residential constructions, especially the two neighborhoods in the developing suburbs. The Plymouth development area even was not occupied by people in 2000.

Notwithstanding the argument that a higher population density is associated with a decrease in travel volume and car usage, the resultant VMT per vehicle and the population density comparison in Figure 5-1 and Figure 5-2 suggest that this dynamic does not always hold true if a new residential development is situated in an improper location. The high-density developments in the developing suburbs (Walpole and Plymouth) generate much higher VMT per vehicle than other developments because they are located in areas with relatively low population densities. This means that these two new housing developments exist as islands in sparsely populated areas. Two other developments with similarly high population densities in Peabody and Westwood produce nearly the same (or even lower) VMT per vehicle as their neighboring areas. This phenomenon reveals that people who are inclined to move to suburban areas mainly prefer to travel by vehicle, as opposed to those who are willing to move to more densely populated areas. In other words, high-density developments in more urbanized areas are
more likely to attract people who have travel patterns similar to those of their neighbors. Therefore, heavily populated residential projects within relatively dense neighborhoods will likely generate travel demands that are less than or equivalent to those of neighboring areas.

Figure 5-1: Comparison of Population Density of Residential Areas
Figure 5-2: Population Density and VMT

Population Density VS VMT per Vehicle

Population Density VS VMT per Household
On the other hand, although situated in the inner core or the regional urban center, the low-density developments in Melrose and Gloucester, which are single-family housing developments, still produce higher VMT per vehicle than their surrounding areas. The Melrose development even attains VMT per vehicle as high as the developments in the developing suburbs. This result indicates that low-density developments cut off from heavily populated areas are more likely to display shorter travel distances but higher travel frequencies; this ultimately gives rise to higher VMT per vehicle. The development in Danvers has a slightly lower population density but produces lower VMT per vehicle than the surrounding areas, while the Bedford one has similar population density and thus produces VMT per vehicle similar to the surrounding areas.

By comparing VMT per household and population density for each development, we can observe that low densities correspond to low VMT per household, which is expected. However, extremely low VMT per household indicates potential errors in estimating household number and total VMT. Apart from that, there is no obvious correlation between population density and VMT per household. Similar relations also exist with other built environment characteristics. Therefore, we will focus on the relationship between selected variables and VMT per vehicle in the following discussions.

To further explore the relationship between population density and resultant VMT per vehicle, I plot the difference in population density and VMT vehicle between the development areas and the neighboring areas as shown in Figure 5-3. With the exception of the Westwood development, the curve generally exhibits a “U” shape, which means
the bigger difference in population density in the development area and the surrounding area (negative or positive) seems to result in greater VMT per vehicle in the development area than that in the surrounding area.

**Figure 5-3: Difference in VMT per Vehicle and Population Density**

Therefore, according to the population densities of the developments and their surrounding areas, we can infer that it is better to allocate high-density developments to more urbanized areas, and low-density developments to areas with similar backgrounds. Under such circumstances, the new residents are more likely to have travel patterns similar to those of the existing residents.
5.1.2 Road density

Road density is another indicator relating to travel demand. Conceptually, new developments constructed in higher road density areas might produce less VMT than those in lower road density areas. However, there is no concrete evidence to support the claim that higher road density is associated with lower travel demand. Especially at the residential development level, the impacts of road density on the travel behavior of new residents within the development areas or the neighboring areas remain uncertain. For the selected nine development projects, the road densities for the development areas, the surrounding areas, and the entire town are shown in Figure 5-4.

With respect to road density, there is no substantial difference between the developments and their neighboring areas, with the exception of the Melrose and Concord developments. It seems that the Melrose project, a single-family housing development, occupies a site that is not as accessible as the rest of the town. This makes sense because the inner core community normally has limited space for new developments. Conversely, the Concord project has a relatively higher road density than its adjacent area and town. Nevertheless, both the Concord and Melrose developments generate higher VMT per vehicle than their towns and other projects in the maturing suburbs (Figure 5-5). The Plymouth, Westwood, and Peabody projects and their neighboring areas have relatively higher road densities than the average level of the entire town. Therefore, a relatively more accessible area was chosen for those developments; this may generate less VMT. However, this is not the case for the Plymouth development. Intuitively, the road density should be lower in suburban areas, but this
trend is not obvious for these projects. Therefore, for the selected residential developments, there is no clear evidence that road density has an influence on the resultant VMT indicators. Road density is likely to affect the propensity to travel on a regional scale, but it seems to have little impact on local travel patterns.

Figure 5-4: Comparison of Road Densities
5.2 Land Use

Since the distribution of land use determines the location of human activities, and transport is required to overcome the distance between these locations, land use should greatly affect peoples’ travel patterns at the local level. If various types of land use, such as residential, industrial, and commercial, are concentrated, residents are more likely to travel shorter distances for working, shopping, education, and leisure. Based on the 2005 land use map provided by MassGIS, I calculated land-use mix index for each grid cell intersecting with the town’s boundaries using the method by which Diao (2010) computed the 2000 land-use mix index. The average 2005 land-use mix indices for the
development areas, the neighboring areas, and the towns are shown in Table 5-2, together with those for 2000, as calculated by Diao.

Table 5-2: Land-use Mix for Each Development in 2000 and 2005

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>Development Area</th>
<th>Neighbor Area</th>
<th>Background (Town)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>0.745</td>
<td>0.393</td>
<td>0.248</td>
</tr>
<tr>
<td>Avalon at the Pinehills, Plymouth</td>
<td>Developing Suburbs</td>
<td>0.446</td>
<td>0.091</td>
<td>0.110</td>
</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>0.307</td>
<td>0.320</td>
<td>0.284</td>
</tr>
<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>0.707</td>
<td>0.529</td>
<td>0.361</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>0.382</td>
<td>0.241</td>
<td>0.215</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>0.027</td>
<td>0.150</td>
<td>0.185</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>0.094</td>
<td>0.216</td>
<td>0.153</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>0.438</td>
<td>0.250</td>
<td>0.114</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>0.652</td>
<td>0.423</td>
<td>0.320</td>
</tr>
</tbody>
</table>

It is not surprising that the 2005 land-use mix indices for most of the development areas are lower than those for 2000. New housing developments converted those areas into homogeneous residential land use, which definitely reduced the land-use mix indices. The Westwood and Concord developments are exceptions, probably because these two projects are located on the edge of residential areas, and the developments introduced different land uses. The land-use mix indices for the surrounding areas also suggest that the neighborhoods where the two developments are sited changed from single-use to multi-use areas within the past five years. The same phenomenon occurred
in the neighboring areas of the Plymouth development; however, no dramatic transformations took place in the neighborhoods of other developments.

By comparing the land-use mix indices for 2005 (Figure 5-6 and Figure 5-7), we can conclude that a highland-use mix in the development areas does not directly bring about equal or fewer VMT per vehicle in the development areas than that in the neighboring areas. The Walpole development in the developing suburbs, the Gloucester development in the regional urban center, and the Concord development in the maturing suburbs all display high land-use mixes in their development areas. Their travel distances (VMT per vehicle), however, are higher than those of their neighborhoods due to relatively low land-use mixes in their surrounding areas.

Conversely, the land uses in some developments, such as the Bedford development, are not well mixed, but their neighboring areas have equal or higher land-use mixes; their residents are more likely to have travel behavior similar to that of their neighbors. The only aberrant case is the Melrose development, which is an isolated single-family housing project located the inner core area. The high travel frequency offsets the advantage of a shorter distance travelled by its residents, which results in a higher VMT per vehicle than its contiguous area.
Therefore, it is the high land-use mix in the surrounding areas that leads to the resultant travel demands of new residents similar to or even lower than those of existing residents in the nearby areas. A residential development cut off from other nearby neighborhoods, no matter where it is located, will increase its residents’ travel demands, which has negative ramifications for local sustainability.
5.3 Location in Town

Location is another factor that may have significant implications for changes in the travel behavior of local residents. Today, most parts of the Metro Boston area are serviced by highways and are equally accessible. The relatively low driving cost (e.g., no fee for road usage) encourages private travel by driving rather than by public transit, cycling, and walking. For the nine selected developments, I chose the distance to the closest form of public transit (i.e., subway stations, commuter rail stations, MBTA bus stops), and the distance to major roads (including limited access highway, multi-lane highway without limited access, numbered route, and other major roads, arterials, and collectors) to
represent the locational features of each development.

5.3.1 Distance to the closest public transit

The comparison in Figure 5-8 and Figure 5-9 primarily focuses on the differences between the developments and the average levels of their towns. I calculated only the average distance for the residential areas in the towns. The data confirm that longer distances from public transit (e.g., the Plymouth and Walpole developments) will result in longer driving distances, especially where large multi-family housing developments are concerned. However, proximity to the public transit system does not definitively result in shorter travel distances. Only the Peabody and Bedford developments exhibit the trend that living closer to public transit provides new residents with more travel alternatives, which may produce less travel demand by driving, than in other areas further away from public transit.
Therefore, the decision on the part of new residents to use public transit does not solely depend on proximity to it. The development type, which is closely associated with the demographic characteristics of residents, and the walkability of local built environment may also contribute to this issue.
5.3.2 Distance to major roads

The distance to major roads is another controversial locational feature. It is well accepted that living close to major roads will result in shorter travel distances, yet the influence on travel frequency is uncertain. For this study, I calculated the average distance to major roads only for residential areas to compare the variations between the development projects, and the differences between the development areas and their towns (Figure 5-10 and Figure 5-11).
For the nine selected projects, generally speaking, the VMT per vehicle increases as distance to major roads increases. This relationship varies across different community types. For instance, as 40B projects, the Walpole, Westwood, and Bedford developments are on average 65–75 meters away from the nearby major roads. However, Walpole, as it is located in the developing suburbs, generates 3000 miles higher VMT per vehicle than
the Bedford development, and even twice the VMT per vehicle as the Westwood
development.

On the other hand, the Melrose development, although sited in the inner core area, exhibits a much higher VMT per vehicle than its neighboring areas and even other developments. This is due to Melrose’s considerably longer distance to major roads relative to its adjacent neighborhoods. Aside from the Melrose development, all other developments have shorter distances to major roads than the average levels of their towns, but they produce either higher, lower, or equal VMT per vehicle in comparison to their towns. From this point of view, the influence of distance to major roads on the travel behavior of new residents is neither apparent nor great.

Figure 5-11: Distance to Major Roads and VMT per Vehicle
5.4 Other characteristics

In this section, two other characteristics—job accessibility and neighborhood building age—are examined to see whether they are closely related to the resulting differences in travel demand between the development areas and the neighboring areas for all selected developments.

5.4.1 Job accessibility

Studies have indicated that workplaces constitute another important determinant of mobility within and between housing developments (Tosics, 2004). This is because the locations of workplaces primarily determine daily travel distances, especially for full-time employed residents. The job accessibility indicator for each area shown in Figure 5-12 and Figure 5-13 is derived from the job accessibility variable computed by Diao (2010) at the 250m grid cell level. I averaged the job accessibility for all populated grid cells (population is greater than zero) intersecting with the development areas, the neighboring areas, and the towns.

In general, the developments with a high level of job accessibility have a propensity for less travel demand. The Avalon community in Plymouth apparently has much lower job accessibility than the Bedford and Peabody communities. Although the Bedford development exhibits nearly the same job accessibility level as the Peabody development, its slightly higher VMT per vehicle implies that its non-work journey-related distance is greater than that of the Peabody development. This same dynamic is
evident in the Melrose development, where residents have shorter job-related travel distances, but much longer non-work journey-related distances, which ultimately leads to a higher VMT per vehicle than its nearby neighborhoods. All 40B projects in the maturing suburbs display very similar pattern in terms of job accessibility. This pattern mostly results from the decentralization of jobs in the Metro Boston area.

**Figure 5-12: Comparison of Job Accessibility (Residential Areas Only)**

![Bar chart showing job accessibility comparison](chart.png)
Therefore, new residents are likely to have daily journey-to-work demands similar to those of existing residents in development areas with comparable levels of job accessibility to their nearby neighborhoods. Non-work travel-related distance to a large extent accounts for the differences in VMT per vehicle between areas with comparable job accessibility levels.

5.4.2 Neighborhood building age

Residents in traditional neighborhoods have a tendency to travel less than those in modern neighborhoods (Greene, et al., 2011). To examine the potential effects of neighborhood building age on the travel behavior of residents in the selected projects,
based on reported building ages obtained from 2000 census data, I roughly calculated the average building ages for the surrounding areas and towns.

From the results listed in Table 5-3 and Figure 5-14, we can see that the Peabody development is situated in the oldest neighborhood compared to other developments; people moving to this residential area are more likely to follow the lifestyle of existing residents. In contrast, the Danvers and Gloucester developments are located in relatively younger neighborhoods, which may result in more variation in the travel patterns of new residents. The rest of the developments are all located in identical neighborhoods in terms of building age. Therefore, the influence that neighborhood building age has on the transport-related consequences of the residential developments in question is not particularly apparent.

Table 5-3: Housing Age of Neighboring Areas

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>Neighbor Area (750m)</th>
<th>Background (Town)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>Avalon at the Pinchills, Plymouth</td>
<td>Developing Suburbs</td>
<td>49</td>
<td>44</td>
</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>51</td>
<td>59</td>
</tr>
<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>48</td>
<td>47</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>48</td>
<td>49</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>48</td>
<td>46</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>37</td>
<td>49</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>56</td>
<td>53</td>
</tr>
</tbody>
</table>
5.5 Summary

To sum up, the transport-related consequences (positive, negative, or almost no impact on local sustainability; see Chapter 4) and the corresponding built environment characteristics for each development are summarized in Table 5-4. The percentages were calculated by dividing the difference in each built environment variable between the development area and the neighboring area, by the value for the neighboring area. The positive percentages indicate that the built environment indicators have higher values in the development areas than in the surrounding areas. The higher the percentages are, the greater the differences between the development areas and their adjacent areas are.
The two 40B projects in Westwood and Danvers exhibit sustainable residential developments in suburban areas by generating lower VMT than their surrounding areas and their towns. The Danvers development is well-integrated into local residential areas in spite of its relatively low population density. The development’s fairly high road density, high land-use mix in the development area and the neighboring area, proximity to major roads, and moderate job accessibility shorten the travel distances (VMT per vehicle) and travel demands (VMT per household) of its residents. Likewise, although the Westwood development is located on the edge of the existing residential area, as a housing development accommodating more than 100 elderly people, it also has a slightly higher population density, a higher road density, a higher land-use mix feature than its neighborhoods, and moderate job accessibility, which together lead to the lowest VMT per vehicle and VMT per household among the nine projects.
## Table 5-4: Summary of Built Environment Characteristics Comparison

<table>
<thead>
<tr>
<th>Project Town Name</th>
<th>Community Type</th>
<th>VMT Indicators</th>
<th>VMT</th>
<th>Density</th>
<th>Land Use</th>
<th>Location</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>VMT/Vin</td>
<td>VMT</td>
<td>Neib</td>
<td>Neib</td>
<td>Neib</td>
<td>Neib</td>
</tr>
<tr>
<td>Walpole</td>
<td>Developing Suburbs</td>
<td>VMT/Vin</td>
<td>9.6%</td>
<td>18.9%</td>
<td>3533</td>
<td>557%</td>
<td>3766</td>
</tr>
<tr>
<td>Plymouth</td>
<td>Developing Suburbs</td>
<td>VMT/Vin</td>
<td>16.1%</td>
<td>18.8%</td>
<td>1873</td>
<td>400%</td>
<td>5292</td>
</tr>
<tr>
<td>Melrose</td>
<td>Inner Core</td>
<td>VMT/Vin</td>
<td>45.0%</td>
<td>45.6%</td>
<td>651</td>
<td>-63%</td>
<td>3545</td>
</tr>
<tr>
<td>Danvers</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>-10.9%</td>
<td>-7.3%</td>
<td>545</td>
<td>-34%</td>
<td>7979</td>
</tr>
<tr>
<td>Bedford</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>2.9%</td>
<td>3.8%</td>
<td>520</td>
<td>-3%</td>
<td>3297</td>
</tr>
<tr>
<td>Westwood</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>-43.9%</td>
<td>-41.5%</td>
<td>1831</td>
<td>102%</td>
<td>7042</td>
</tr>
<tr>
<td>Concord</td>
<td>Maturing Suburbs</td>
<td>VMT/Vin</td>
<td>12.3%</td>
<td>12.0%</td>
<td>1027</td>
<td>161%</td>
<td>8513</td>
</tr>
<tr>
<td>Gloucester</td>
<td>Regional Urban Centers</td>
<td>VMT/Vin</td>
<td>7.2%</td>
<td>8.1%</td>
<td>485</td>
<td>33%</td>
<td>2226</td>
</tr>
<tr>
<td>Peabody</td>
<td>Regional Urban Centers</td>
<td>VMT/Vin</td>
<td>0.2%</td>
<td>-3.2%</td>
<td>3965</td>
<td>222%</td>
<td>10309</td>
</tr>
</tbody>
</table>
The two Avalon communities in Peabody and Bedford can be regarded as good examples confirming my hypothesis that new residents would exhibit travel behavior similar to that of nearby existing residents (i.e., VMT per vehicle similar to the neighboring areas and towns). Either positive or negative impacts in terms of VMT per household result only from the effects of different densities. The Bedford development displays a comparably low density, but one similar to its surroundings and town level, while the Peabody project demonstrates an extremely high-density housing development that is integrated into a more densely populated neighborhood. Meanwhile, both have moderate land-use mixes in their neighborhoods, shorter distances to public transit, modest distances to major roads, relatively high job accessibilities, and older neighborhood backgrounds. Under such conditions, new residents may tend to travel as much as the nearby residents do.

The residents in all other developments seem to have greater travel demands, which is deemed to be a less sustainable lifestyle. The most extreme cases are the Melrose low-density housing development in the inner core, and the two high-density housing developments in the developing suburbs. The high travel demand produced by these developments mostly results from a mismatch between the development densities and the surrounding densities. Certainly, for the Melrose development, aside from its isolated location and low density compared to its neighboring areas, frequent non-work-related trips, a lower road density, a low land-use mix, and its considerable distance from major roads exasperate the situation. Much lower densities in the neighboring areas, low road densities, lower land-use mixes in the surrounding areas, longer distances to public
transit and major roads, and low job accessibility together result in longer travel distances for the two suburban developments. This is also considered an unsustainable urban growth pattern.

Therefore, although all 40B projects (Walpole, Danvers, Bedford, Westwood, and Concord) and Avalon communities (Plymouth, Bedford, and Peabody) share similar built form, the differences in the geographic location and built environment lead to different impacts on local sustainability from a transport-related perspective.
Chapter 6: Conclusion and Discussion

Both regional government and local governments desire to reduce the need to travel and issue guidance on how this objective may be achieved. However, they lack clear evidence as to the impacts of different urban forms and housing development patterns on change in travel demand. As a noticeable component of urban form, local residential developments may have great influence on local and regional sustainability. This thesis has proposed an analytical framework to reveal different transport-related impacts of new residential developments located in different types of communities, to examine whether new residents have travel pattern similar to existing residents, and to explore why such impacts differ across the selected developments by analyzing the built environment characteristics for each development.

This concluding chapter first summarizes the findings in the preceding chapters, then points out the limitations and challenges of the study, and finally suggests potential future research.

6.1 Research Findings and Implications

The analysis of this study is categorized into two sections. The first section illustrated the transport-related impacts of individual residential developments and how such impacts vary across the selected developments (Chapter 4); the second section examined the underlying built environment characteristics of the development areas and their
surrounding areas that may cause the differences in resultant transport-related impacts (Chapter 5).

The results in Chapter 4 suggest that residential developments do have impacts on local sustainability in terms of VMT indicators. Developments within the built-up area of larger residential areas show different transport-related consequences than those in suburbs or outside the expanded residential areas, even if those developments have similar forms (40B projects or Avalon communities). Among the nine selected projects, those located in the developing suburbs (Walpole and Plymouth) apparently generate higher VMT per vehicle than other projects. New residents do not always have travel patterns exactly the same as those of existing residents in the nearby areas. They are greatly influenced by the development type and the built environment characteristics of neighboring areas, even though the new residential developments are situated in the same type of communities.

The 40B developments in Danvers and Westwood can be considered more sustainable than the others because of their shorter travel distance, fewer cars, or denser development. The Avalon communities in Peabody and Bedford are two examples confirming my hypothesis that new residents would exhibit travel behavior similar to that of nearby existing residents (i.e. VMT per vehicle similar to the neighboring areas and the towns). Other 40B projects (Walpole and Concord), Avalon community (Plymouth) and single-family housing developments (Melrose and Gloucester) have greater travel
demand than their neighboring areas due to their different geographic locations, which is deemed to be a less sustainable lifestyle.

Chapter 5 examined the built environment characteristics of the selected developments and their neighboring areas to reveal the underlying factors that may lead to the differences in VMT indicators. The results suggest that:

1) Low-density development in a densely populated area and high-density development in a sparsely populated area tend to encourage more travel demand than in neighboring areas. High-density developments should be positioned in places where the existing neighborhood is already relatively mature;

2) Developments isolated from current residential areas are less desirable in terms of sustainability (Plymouth and Melrose). It is better to locate new developments in areas that are well-integrated into (Danvers and Peabody) or at least on the edge of existing residential areas;

3) High land-use mix in the neighboring areas is important for reducing car-based travel (Danvers and Westwood);

4) Under certain circumstances, new residents may be inclined to travel as much as the nearby residents do (Peabody and Bedford): population density similar to the neighboring area or high-density development integrated into surrounding residential
areas, high to moderate road density, high to moderate land-use mix in the adjoining areas, not far from the public transit or major roads, high to moderate job accessibility, and relatively old neighborhoods;

5) Locating developments in places that offer more transport choices does not definitely have the effect of reducing travel demand if in fact people there get used to using cars extensively and will continue to do so.

6) The differences in VMT across the selected developments are caused not only by work-related travel (e.g. Plymouth and Gloucester) but also non-work trips (Melrose).

No matter how strong the support from local governments for reducing car-based travel, if there is no clear evidence as to why one particular housing development pattern should be preferred over another, it is unlikely that this issue will affect decision making. Although the findings in this study cannot provide definitive guidance on how to locate a residential development in the best place, they at least suggest what kind of development is less desirable from a sustainability point of view.

The results also imply that local planning authorities can exert a substantial influence on the amount of car-based travel through the strategic location of new housing. The relationship between the required scale and existing developments should be taken into account as well. However, the allocation of land for new housing development, the focus of this study, is arguably the most important element in development plans.
While findings from this study can contribute to planning practice in general, they also can hold implications for the MetroFuture plan and scenario planning in the Metro Boston area. The MetroFuture plan has provided the guidance for future housing allocation at the regional level. However, how to guide individual developments conforming to regional plans to achieve sustainability is still uncertain. For residential developments, especially large housing estates, interventions were needed to ensure the sustainability of residential developments. In addition, the findings may assist in scenario analysis for proposed residential developments in terms of potential impacts on local sustainability.

6.2 Limitations and Challenges

This study faced several limitations and challenges.

First, for such impact analysis, larger development projects are preferable, e.g. larger than 20 acres (6~7 grid cells included in the developed area). Size is also not a critical criterion in the process of project selection. However, with the improvement of developments, we should be able to identify more large development candidates that allow us to confirm some implications that have been drawn from this study.

Second, estimating household number and population at a fairly fine resolution is still a challenging task if using steadily available spatial data, such as census data on a block group level. However, such datasets at least provide raw material that enables us to obtain these demographic data over time and across the Metro Boston area. Refinement
of data allocation from a census block group level to a more spatially detailed level would definitely assist in further verifying the findings in this study and perceiving more valuable phenomena.

Finally, we must be cautious about interpreting some information that may result in abnormal travel demands, such as the lower VMT in the Westwood development due to the large number of elderly people residing there. It is highly likely that some locations are more attractive than others to people who have particular car-travel preferences. The travel behavior that is observable at particular locations exists partially because people have chosen to live there rather than because of other accessibility characteristics of those places. Therefore, we should pay attention to the demographic information about the selected developments that may support or confirm the final findings.

6.3 Future Research

Studies have confirmed that proper housing development and land-use policies may play a crucial role in preventing dispersed development and urban sprawl (Tosics, 2004). Further research on how to allocate new housing developments to conform to local and regional goals regarding urban sustainability is exigent. The analysis proposed here is a preliminary approach to addressing this complicated issue. There are several major potential extensions of the current study:

1. Refinement of current methodology
Calculating VMT indicators on a fine scale is challenging without more spatially detailed data inputs. Along with more available and reliable RMV odometer readings, census data and spatial data in the future, VMT per vehicle, VMT per household and other transport-related measures can be further refined in terms of relative information, such as number of vehicles and number of households, for small-scale analysis. Meanwhile, the estimation of the built environment characteristics for the projects can be further improved as well. Therefore, as these datasets become more detailed and standard, it will be easier to reduce measurement error and track trends over time.

2. Detailed demographic information

New housing developments not only are very specific in their locations but also tend to attract particular segments of the population and thus have distinctive travel-generating characteristics. Apart from context factors, personal preferences may also influence travel behavior at the new residence. Therefore, it would be useful to acquire more demographic characteristics for analyzing possible travel patterns of new residents and predicting potential increase in travel demand for other new developments. The latest version of American Community Survey (ACS) five-year estimates has been released recently, which may provide more demographic information on existing residential developments. In addition, a household survey may assist in obtaining more personal information about travel preferences, although it is expensive, labor-intensive, and time-consuming process.

3. Data integration and consistency
Although extensive datasets have been explored in this study, it would be better to integrate the data for different periods and from different sources. VMT indicators are calculated using odometer readings from 2005 to 2008. The population data comes from 2010 census data on a block group level. Some built environment indicators, such as road density and distance to the closest public transit, are computed based on spatial data on 250m-grid cell level in 2000. We should be able to find a more effective, scalable, and sustainable approach for analyzing data when such data collection becomes more standard and routine.

To summarize, further research is needed to provide more in-depth insights into the impacts of individual residential developments on local car-based travel and to generate more useful data and evidence for making decisions on what kind of housing developments should be proposed and where they should be located.
References


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MAPC.2010.8. “Metro Boston Consortium for Sustainable Communities - Sustainable Communities Regional Planning Grant Program Final Application,” Boston, MA. 
[http://www2.mapc.org/SusCom%20Drafts/MetroBoston_Sustainable_Communities_FINAL_8_23_10.pdf](http://www2.mapc.org/SusCom%20Drafts/MetroBoston_Sustainable_Communities_FINAL_8_23_10.pdf)


Appendix:

Appendix 1: Aerial Photographs of Neighboring Areas

Gatehouse Preserve LLP, Walpole
Avalon at the Pinehills, Plymouth
Nordic Way Subdivision, Melrose

Endicott Green, Danvers
Avalon at Great Meadows, Bedford
Highland Glen Expansion, Westwood

Fairhaven Residential Gardens 40B, Abbott Lane, Concord
Magnolia Estates, Gloucester
Avalon Essex, Peabody
### Appendix 2: VMT per Household Using Household Numbers in 2000

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>Devlp Area</th>
<th>Neighbor Area (750m)</th>
<th>Background (Town)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
<td>Developing Suburbs</td>
<td>83807</td>
<td>38073</td>
<td>30250</td>
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<tr>
<td>Avalon at the Pinehills, Plymouth</td>
<td>Developing Suburbs</td>
<td></td>
<td>69788</td>
<td>47059</td>
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<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>16332</td>
<td>16900</td>
<td>15594</td>
</tr>
<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>79236</td>
<td>128326</td>
<td>39005</td>
</tr>
<tr>
<td>Avalon at Great Meadows, Bedford</td>
<td>Maturing Suburbs</td>
<td>34114</td>
<td>30911</td>
<td>25798</td>
</tr>
<tr>
<td>Highland Glen Expansion, Westwood</td>
<td>Maturing Suburbs</td>
<td>11081</td>
<td>21892</td>
<td>27408</td>
</tr>
<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
<td>Maturing Suburbs</td>
<td>27032</td>
<td>28754</td>
<td>30293</td>
</tr>
<tr>
<td>Magnolia Estates, Gloucester</td>
<td>Regional Urban Centers</td>
<td>43524</td>
<td>60647</td>
<td>35815</td>
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<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>17428</td>
<td>28322</td>
<td>25578</td>
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</table>
### Appendix 3: Household and Population Allocation in 2010

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Community Type</th>
<th>Development Area</th>
<th>Neighboring Area</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of Grids</td>
<td>No. of HH</td>
<td>Pop</td>
</tr>
<tr>
<td>Gatehouse Preserve LLP, Walpole</td>
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<td>7</td>
<td>136.79</td>
<td>27.72</td>
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<td>21.93</td>
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</tr>
<tr>
<td>Nordic Way Subdivision, Melrose</td>
<td>Inner Core</td>
<td>4</td>
<td>4.79</td>
<td>20.01</td>
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<tr>
<td>Endicott Green, Danvers</td>
<td>Maturing Suburbs</td>
<td>5</td>
<td>12.41</td>
<td>304.96</td>
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<tr>
<td>Avalon at Great Meadows, Bedford</td>
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<td>8.07</td>
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<td>60.19</td>
<td>91.24</td>
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<tr>
<td>Fairhaven Residential Gardens 40B, Concord</td>
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<td>11.79</td>
<td>182.56</td>
</tr>
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<td>Regional Urban Centers</td>
<td>4</td>
<td>11.61</td>
<td>13.26</td>
</tr>
<tr>
<td>Avalon Essex, Peabody</td>
<td>Regional Urban Centers</td>
<td>3</td>
<td>94.66</td>
<td>26.91</td>
</tr>
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