AN ANTIDOTE TO SPRAWL? : EVALUATING IMPACTS OF RAIL TRANSIT ON URBAN STRUCTURE
– A CASE STUDY OF PORTLAND METROPOLITAN AREA, OREGON

By

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To my Mom and to my Dad
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Abstract of Thesis Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Master of Urban and Regional Planning

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By

Xinyuan Yang

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Chair: Ruth L. Steiner
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In the era of sprawl, transit development is favored by a large number of transportation planners as a planning approach to incentivize compactness and control sprawl. This study is developed to examine the effectiveness of investing in rail transit infrastructure as a regional anti-sprawl strategy in Portland metropolitan area from 1990 to 2010. While the Portland metropolitan area has become less concentrated, there is a gradual agglomeration of population along the transit corridor from 1990 to 2010. Through cross-time and cross-scale comparisons of OLS model results, it has been found that rail transit plays a positive role in facilitating compact growth and such effects are more localized around the station areas. However, the effect of transit expansion on sprawl is relatively more inconclusive. Based on a binary logistic regression model and qualitative analysis, urbanization over the study period is primarily driven by the highway accessibility. Transit expansion as a regional strategy is not enough to alter commuters' travel behavior and further curb the sprawl.

Portland metropolitan region is a unique case as it has an elected regional council. So far, Portland seems to be on a right track of planning, which combines
transportation with land use planning, and it already triggered the positive impacts of the planning strategy on urban density. However, more work has to be done in order to truly control the ongoing sprawling process.
CHAPTER 1
INTRODUCTION

1.1 Background

In the US, metropolitan areas have been ‘sprawling’ from central cities due to the increasing automobility. Along with the development spreads out from US cities, the development cost for infrastructure and service provision has increased tremendously. Besides the capital cost, urban sprawl reduces open space and encroaches on a large amount of agricultural land every year. Hence, sprawl and its consequent suburban development are always considered to be out of proportion with demand and resources.

Because of the fragmented development pattern at municipal and regional levels, it is fairly difficult for any community or single project to gain ground in holding back this outward growth trend. As yet however, most movements since 1970s to alleviate the negative impacts of sprawl, including New Urbanism, Transit Oriented Development and Complete Streets, encouraged compact development that has been highly localized to a community or corridor scale. For example, Transit Oriented Development has to be implemented in a walkable radius ranging from 400 to 800 meters according to the TOD’s theoretical principle (Duany, 2001). Both regulatory assessment and capital investment are tightly restricted to the proposed radius. Such localized development evaluation leaves indirect agglomeration effects beyond the project site unaddressed.

It needs to be acknowledged that some programs, such as Smart Growth programs, emphasize the importance of regional solutions to urban sprawl. Nonetheless, the success of such programs can face a huge challenge from the effectiveness of implementation and its integration within the planning context. At present, the metropolitan planning organizations has a coordination role in planning and
programming funds for transportation projects, while land use planning is mainly the
duty of local government (Solof, 1998). While MPOs propagandize transit expansion
project as a key strategy to encourage compact development, there is virtually no
guarantee of regional implementation. Despite the fact that one of the MPOs’ duty is to
allocate federal and other transportation funding resources for new infrastructure,
regional planning and land use coordination, along with transit operation, are less
funded and are not included as one of MPO’s responsibilities (Waddell, 2011).

In spite of the challenge of regional coordination and uncertain regional effects,
developing transit infrastructure, especially fixed guideway transit, is favored by a large
number of transportation planners and professionals as a planning strategy to
incentivize compactness and control sprawl (Mees, 2010). It has been basically
assumed that rail transit will impel denser development around the transit lines and
reduce motorized traffic through the changes in mode choice, which will directly
increase the degree of urban compactness and indirectly alleviate the sprawling
problem. Take Metro Rail system in Los Angeles as an example, one of the Los
Angeles County Metropolitan Transportation Authority’s ambitious objectives of
developing the 87-mile metro system is to attract 7.8 million people to accommodate
within three miles of a metro rail or bus-rapid transit lines. A higher density would also
make public transit more viable in the city. Meanwhile, improvement of the transit facility
is commonly included as a part of Transportation Demand Management Program to
increase the number of commuters by public transportation (Nelson\Nygaard, 2008).

Given these challenges, it is essential for planners to understand the dynamic
relation between regional transportation system and land use planning before such a
daunting task is undertaken. It ensures the strategy is taken for its necessity and effectiveness. More importantly, from an economic perspective, the influence of transportation system on land use pattern is particularly critical as new development along transportation corridor, especially transit lines, is expected to pay partially for transit improvements and community amenities in most cases (CTOD, 2011). Development density and the potential for development along transit corridors directly relate to ‘value capture’ and the effectiveness of the local financing strategy (CTOD, 2011).

1.2 Research Aim

The study examines the impacts of transportation development on urban structure. Particularly, it looks into the effectiveness of investing in rail transit infrastructure as a regional strategy to increase urban density and control sprawl by investigating the changes that have occurred in Portland, Oregon from 1990 to 2010. It assumes that the population in Portland will be more concentrated near transit stations as the accessibility to transit grows. Furthermore, it has been assumed that transportation accessibility, transit accessibility in particular, plays an important role in the urban structure during the formative decades. In other words, the general hypothesis proposed by this study is that fixed rail infrastructure will positively increase urban agglomeration, resulting in a higher degree of regional concentration and a lower degree of sprawl.

To put this hypothesis to the test, this research will firstly look into the urban growth pattern and transit development over 30 years by regionally mapping the hotspots of population and employment together and investigating the descriptive statistics of census tracts along the transit corridor. After that, the population density of
the study area will be regressed by transit accessibility and other influencing features at census group level, to evaluate the impacts of fixed-rail transit on urban density. Next, a land transition model will be presented to examine whether rail transit has greatly influenced the overall rural-urban transformation after 24 years of operation and deconstruct the main driving forces of urban sprawl. Throughout the entire study, both regional and local transit effects will be discussed and compared.

1.3 Detailed Research Objectives

- In general, is there any physical agglomeration of population and employment along transit corridor in Portland?
- Does the transit expansion lead to compact growth by influencing the urban density at both regional and transit corridor levels?
- What is the role of transit improvement in the context of sprawl?
2.1 The Era of Sprawl

An increase in the city size was one of the primary transformations in the 20th century. From a global standpoint, the number of cities with populations of more than one million increased from only 16 at the beginning of 1900s to approximately 500 in 2007. Meanwhile, urban areas are growing dispersed, which no longer featured compact living as they did in the past century (Redman and Jones, 2005). Urban sprawl, which refers to auto-dependent and low-density development, is one of the major development patterns in the United States.

According to Alonso’s bid-rent function theory (Alonso, 1964), some extent of dispersion is desired. The land location choice is a combined result of rent, transport and other costs (Giuliano, 2004). A certain degree of dispersion provides industries, relying on information exchange, with an opportunity to locate near centers at a higher rent (O’Sullivan, 2007); industries and workers with less need for information exchange may have the option to locate away from the center at a lower cost. In this monocentric scenario, land price is a reflection of accessibility and attractiveness of a location.

According to the bid-rent theory (Alonso, 1964), land price is cheaper at the city periphery. In addition, property taxes tied to built land, along with the complex and restrictive land use policies applied in the incorporated region, further drives development from the urban center (O’Sullivan, 2007). For developers, suburban development reduces the overall cost and avoids cumbersome development regulations that intend to recoup the redevelopment cost for cities. In addition, with abundant land, such development can be easily reproduced. Economies of scale will result in a lower
general cost. For consumers, sparse development offers more living and open space. All these reasons make it less attractive to develop densely in the urban area.

Although sprawl is concluded as a natural result of market forces, the proclivities of the populace, and increased mobility owing to technology improvement (Bruegmann, 2008), this decentralized development pattern has become an increasing concern in the recent decades. In United States, along with the higher degree of urban dispersion since 1940 are economic segregation and an unprecedentedly increasing rate of per capita resource consumption, which mainly includes the depletion of land, water and fossil fuels (Alberti, 2005). On top of that, sprawl is more of an environmental issue. While urban areas spread out, transform, and encroach on the suburban landscape, they cause the loss of wildlife habitats and biodiversity, and a greater demand for energy. In terms of the transportation impact, Cervero and Hansen (2002) pointed out that new development of this type triggers new vehicular traffic, with which the traffic demand quickly exceeds the existing road capacity, resulting in increased congestion. As cities spread further out, the congestion will get worse. Moreover, socially, regional sprawl is criticized to cause ‘a decline of community’ and it also poses challenges in planning services throughout the region (Crane, 2008). These issues have attracted public attention and a great number of planning strategies and programs have been proposed to mitigate these problems, but so far only a limited number of qualitative analyses have been done to see the trend (Rosenthal, 2003).

2.2 Dynamics of Transportation and Land Use

Most of the attempted solutions for urban sprawl are developed based upon the interdependent relationship between transportation and land use. Hence, on top of knowing these two are interconnected, it is more crucial to understand the dynamics of
the two. Figure 2-1 briefly presents the relationship. As it shows, although transportation and land use development are mutually dependent, the influences of transportation on land use are realized through the change of accessibility, or the ease of moving among places. It is accessibility that directly affects the activity location and land use pattern. In turn, land use patterns, together with transportation resources, determine daily activity patterns, which further influence travel patterns (Giuliano, 2004). While land use and transportation are major elements of the urban system, accessibility and activity pattern also play an important role in this circle. A great number of empirical studies indicate that accessibility remains one of the principal influencing factors of urban form and urban development (Handy, 1996; Crane, 2008; Scott & Homer, 2008). Accessibility implies the attractiveness based on the opportunities and activities of one place. With more interactions in the system, activities will locate places with higher accessibility. Hence, in a lot of cases, a study about the relationship of transportation and land use, to some extent, is a study on the dynamics of accessibility and land use.

Figure 2-1. Transportation-Land Use Connection (Giuliano, 2004)
This simplified model (Figure 2-1) illustrates the interdependence between transportation and land use. Nonetheless, it does not suggest the strength of these connections. Researchers have attempted to investigate this problem by isolating transportation impact or land use impact, while controlling the rest in Figure 1 and all manners of other influencing factors. However, both the land use system and transportation system are dynamic, which are influenced by diverse contexts and processes. The rapid transition of demography, infrastructure, political environment and technology make it more difficult to separate the role of transportation from all these factors. Giuliano (2004) in her paper *Land Use Impacts of Transportation Investments - Highway and Transit* implies that empirical studies of transportation and land use tend to be inherently problematic due to “the durability of built environment”, “the long lag time of transportation projects”, and “the high costs of relocation” (p. 240).

### 2.3 Relationships between Transit and Urban Growth

As transportation and land use are interrelated, urban land-use pattern influences the use of transit and other travel modes while transit induces the change of urban form. In terms of the impacts of urban form on transit, Parsons Brinkerhoff, Quade and Douglas Inc. (1995) did a comprehensive review of literature on the relationships between transit and urban land use development up to 1994. Among the literature, Smith’s comparative study on the transit usage in six US metropolitan regions (1984) found that residential density can explain the variations of transit usage to a great extent. Similarly, density and other built environment elements were found to be important in explaining the variability of mode choice (Cevero, 1996; Parsons Brinkerhoff, Quade and Douglas Inc., 1996). Conversely, studies (Burby, 1974; Peat Marwick & Mitchell, 1975; Levinson & Kumar, 1993) reported that density has little effect...
on transit usage or VMT based on different datasets. In 2010, Paul Mess (2010) further rebuts the notion that high density should be the premise for transit project. Mess (2010) argues that effective transit and higher density are not inherently related with each other. In Zurich, Switzerland, for example, transit development has been successful without a high-density base (Mees, 2010).

Similarly, no consensus has been reached by previous studies concerning the transit impacts on urban development pattern. Some have concluded with less impact, while others have suggested that transit may greatly influence urban form under certain conditions. Webber (1976) evaluated the impacts of San Francisco’s BART one year after its opening. Since one year was too short to analyze urban form evolution, Webber’s study (1976) mainly focused on the efficacy of BART system in diverting suburban car trips to transit and his analysis concluded with no significant influence of BART on changing auto usage. Besides Webber’s study (1976), a number of evaluations have been conducted, around the same time, at various locations, like Washington D.C., Atlanta, New York and Philadelphia, shortly after their transit system opened (Dvett et al, 1979; Allen et al, 1976; Pushkarev & Zupan, 1977). Few of these assessments found significant impacts of transit on development patterns mainly due to the short analysis period.

In the project named ‘BART @ 20 Update Study’, Cervero and Landis (1997) looked into the relationship between BART and land use after 20 years of operation. In this in-depth study, the research scale ranged from super-districts to grid cells. It has been generally concluded that BART has significantly varied influences across the study area. Downtown San Francisco has been greatly affected by BART system. In the
broader region, BART attributed to the polycentric settlement pattern. However, it was local redevelopment authorities helped to bring about the multi-family residential units around the suburban stations by offering various economic incentives and local rezoning. Therefore, it was concluded that BART, itself, may not generate large-scale land use change, however, it can have a big influence under the right circumstances (Cervero and Landis, 1997).

In the study of Atlanta MARTA, Bollinger and Ihlandfeldt (1997) modeled population and employment change based on census tracts in 1980s. The variables tested in the model include employment accessibility, proximity to MARTA, employment in previous period and other control factors. According to the model result, only the station category of mixed-use regional node was significantly related to the employment change, while none of the MARTA-related indicators was a significant influencing factor of population growth. At the end of the study, Bollinger and Ihlandfeldt (1997) concluded that MATRA had no significant impact on the increase of population and employment, but it partly explained the increase in the proportion of public employment around some stations. An analogous study on the influences of MATRA on population and employment location was conducted by Nelson and Sanchez (1997). By investigating the absolute number and the regional share of population and employment within one-half mile of stations, they found drops in both the absolute number and the regional share of population within the station catchment area. However, the employment number increased around the station with a decline in the regional share, showing that the job growth outside the station catchment area was much greater (Nelson and Sanchez, 1997).
Compared with Atlanta, Miami has a larger share of elderly population and higher population density as premises of its transit project. One study by Gatzalaff and Smith (1993) evaluated the impacts of Miami Metrorail on property value. In this study, they maintained that the change of land price will inform the land use change over time and such measure is good for assessing accessibility-related influences. By controlling for factors before/after the approval of the system and for the distance to the nearest stations, the model suggested a result to the contrary of the hypothesis: access to transit stations has little influence or a negative influence on land price. Gatzlaff and Smith (1993) attributed this result to the lack of ridership, which failed to cause change in accessibility. Meanwhile, planners intended to use Metrorail to revitalize the economically disadvantaged region, and therefore placed the transit out of the economic corridor of Miami. This intention also partly explained the result (Gatzlaff and Smith, 1993).

There is a large volume of published studies describing the role of transit on land use change. On top of the literature discussed above, there is more beyond the scope of this study. Badoe and Miller (2000) comprehensively reviewed the literature on this topic, which might offer more references.

With a review of the diversified findings on the effect of fixed-rail transit, several notable points can be drawn from these studies. Firstly, the length of analysis time period will possibly influence the result. The time scale of some studies, such as Weber’s study (1976) on BART involves, are too short for land use to respond the transit development. The short-term effects are not indicative of long-term responses. However, over the long run, plenty of influencing factors may change, making it more
difficult to separate the role of transit. Additionally, data availability over a long time period may also impact the quality of long-term study. Secondly, the study conclusions can vary due to the applied methods and the study scope. No two locations’ development is under the effect of identical forces and one location’s development can be influenced by completely opposite forces over time, therefore, how the method is constructed - whether it is a ‘before-after’ study based on statistical models or a cross-sectional study based on a descriptive comparison, whether it is a project-level study or a regional-scale analysis – will also influence the final conclusion. Thirdly, the variation of variables can result in the diversity in results. The change of urban form is a mixed result of all evolutionary forces at work. Properly controlling all the factors and isolating the transit effect are notably challenging under such circumstances. Most studies are capable of identifying and controlling only a limited number of influencing factors.

2.4 Urban and Regional Planning in the Context of Sprawl

As urban sprawl has been regarded as a planning issue, much of the current literature pays particular attention to different approaches to remedy the problems related to sprawl. At the center of this ‘anti-sprawl’ stage are concepts such as Smart Growth, Traditional Neighborhood Development (TND), and Transit Oriented Development (TOD). All of these strategies focus on densifying development around city centers and subcenters. Walkable designs are promoted under these concepts to create a sense of place. While Smart Growth is described as a concept, TOD is more perceived as one form of Smart Growth, as it builds on a stricter and narrower development framework (Nelson, 2002). It focuses on increasing compact development within a walking distance to transit stations. Meanwhile, it is seen as a means to increase the feasibility of transit projects through accommodating more commuters into
a walking distance (Nelson & Lang, 2009). Based on these definitions, TOD projects are planned at local scale centering on transit stations. In addition, according to the TOD’s strict framework, TOD requires a careful calibration of changes to the planning and built environment (Nelson & Lang, 2009). These factors restrict the regional application of this concept.

Regionally, developing transit infrastructure, especially fixed rail transit, is favored by a large number of transportation planners and professionals as a planning strategy to incentivize compactness and control sprawl (Richardson & Bae, 2004). However, when MPOs tout and allocate federal funding for transit projects, the land use decisions around the transit investment are on the hand of local municipalities with home rule. To overcome this jurisdictional deficient, some municipalities, such as Portland, OR, go by turning over their home rule capabilities to regional authority; some, like Salt Lake City, go by communicative advocacy. According to Montgomery (2011), several MPOs adopted strategies aiming to coordinate transit and land use, which include incentivizing land use changes around transportation corridors and funding plans connecting transportation infrastructure with land use.
CHAPTER 3
RESEARCH DESIGN

To achieve the research objectives and aim, a mixed methodology is applied in this project, including case study, descriptive analysis, and regression analysis. A longitudinal approach is adopted to explore the changes of transit impact on urban density in the past statistical years. Urban growth pattern is typically studied based on the years of 1990 and 2010.

3.1 Case Study: Greater Portland Area

Portland, OR metropolitan area was chosen as the study case for this project (Figure 3-1). Historically, Portland had streetcar lines although they became obsolete by the 1950s (PdxHistory, 2013). The first modern rail line in Portland opened in 1986 and the rail transit system will be expanded to have five MAX lines and one WES line by the end of 2015 (Rose, 2014). By 2010, four rail lines were in service. The analysis period of this study is from the opening of the first line in 1986 to 2010. The population statistics and land use information in 1990 and 2010 will be specifically compared and analyzed. This 20-year period is expected to be long enough for land use to respond the transit development and expansion. Considering that the MAX rail system continuously expands during the recent decades, it is also assumed that there are substantial incentives that buttress this costly decision.

In this study, a two-mile buffer of the transit line is defined as the transit corridor and is used to investigate the local transit effect as a comparison to the regional impact. Although the setting of two miles is longer than the walking distance formulated in the TOD concept, this distance is in a reasonable range, in which transit benefits are expected. For example, metro development in Los Angeles is anticipated by Los
Angeles County Metropolitan Transportation Authority to increase the density within three miles of a metro rail. Meanwhile, two miles is an acceptable distance for ‘bike and ride’ or ‘park and ride’ (two miles is about the distance of ten-minute cycling or five-minute driving).

In addition, Portland, OR has an elected regional council with one of the most comprehensive regional growth management programs nationwide, including its well-known Transit Oriented Development (TOD) program (Montgomery, 2011). In order to direct growth from suburbs to city centers, a multi-center development pattern has been planned regionally on the basis of rail lines. The problem related to this point lies in that it would be fairly tough to distinguish any growth as influences of transit development or impacts of regional land use scheme.

Figure 3-1. Study Case: Greater Portland Area
3.2 Descriptive and Spatial Analyses of Growth Pattern in the Greater Portland

With the data availability, this part of analyses is conducted on census tract level. The data sources used in this section are presented in Table 3-1. To examine the urban growth trend in Portland Metro Area, population and employment growth at the transit corridor and the regional level are analyzed via descriptive statistics.

Using ArcGIS, a hot spot analysis is carried out to identify regional clusters of high population density along transit lines. This method is drawn from one previous research on polycentric theories of spatial employment (Giuliano et al., 2012). In that study, Giuliano et al. (2012) identified spatial nodes of employment growth and investigated the reasons to such locational growth. The goal of this hotspot analysis is to examine how the number and size of high density clusters spatially change over the expansion of transit corridor.

After a regional glance, the density of population and employment around the transit corridor is closely investigated by comparing the density value of each tract within the corridor to the average density of tracts outside the corridor. Tracts with statistical significance are marked based on the census year. By presenting these maps, this approach attempts to answer the question that whether there is a physical agglomeration of population and employment among the transit corridor over the study period.

The preliminary results of these descriptive and spatial analyses will offer some insights on further exploration on population density and urban development in Portland, OR.
Table 3-1. Data Sources Used in the Descriptive and Spatial Analyses

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<td>(<a href="https://www.census.gov/geo/maps-data/data/tiger-data.html">https://www.census.gov/geo/maps-data/data/tiger-data.html</a>)</td>
</tr>
</tbody>
</table>

3.3 Ordinary Least Square Regression Analysis

While the descriptive statistics and the spatial investigation generally depict the growth pattern of Portland Metropolitan Area, they fail to specify whether this density dispersal is significantly associated with transit development. They also show no indications about the scale and magnitude of density variations. Therefore, a simple multivariate regression model is developed on the census block group scale to test the significance of transit-related indicators in affecting population density. Besides, another two indicators – CBD accessibility and geological slope – are entered in order to stabilize the model. Among these variables, access to CBD is measured by the distance from the centroid of each census block group to city center defined by the 2040 Concept Map, which basically is the location of Pioneer Courthouse Square, downtown Portland. Transfer attribute is defined as a dummy variable, suggesting whether the nearest
station is a transfer point. Besides, Portland overall has a unique landscape feature, where the east part of the city is less steep and consequently better for development when compared with the west part. The geological feature is therefore considered as another significant influence for residential development and population density. In this case, ‘slope’ is a dummy variable included in the models, showing whether this CBG has a larger slope area than the overall mean or a major slope over 41% (Figure 3-2).

![Slope Map of Portland Metropolitan Area](image)

Figure 3-2. Slope Map of Portland Metropolitan Area

The regression models are run at the transit-corridor and regional scales in IBM SPSS, which is a predictive analytics software, to examine the difference of transit effects at various levels. Transit indicators tested in this model include transit accessibility, which is the distance to the nearest transit station from block group centroid, and a dummy variable indicating whether the nearest station from the block group centroid is a transfer station. The data sources used in this section are presented in Table 3-2.
Table 3-2. Data Sources Used in Ordinary Least Square Regression Analysis

<table>
<thead>
<tr>
<th>GEO Dataset</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990 Census Block Groups (CBG)</td>
<td>Metro RLIS Discovery</td>
</tr>
<tr>
<td>2010 Census Block Groups</td>
<td></td>
</tr>
<tr>
<td>1990 Population at the CBG Level</td>
<td></td>
</tr>
<tr>
<td>2010 Population at the CBG Level</td>
<td></td>
</tr>
<tr>
<td>Transit Stations</td>
<td></td>
</tr>
<tr>
<td>Concept Centers</td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>Oregon Department of Forestry</td>
</tr>
</tbody>
</table>

3.4 Binary Logistic Regression Analysis

McFadden (1973) first revealed the suitability of logistic regression for modeling stochastic utility-maximizing choice. This analysis approach has been further extended to investigate discrete events in urban modeling, remote sensing, education, epidemiology and other subjects (Reilly et al., 2009). Logistic regression models have advantages of robustness and tractability facing multicollinearity. With a view to relevant studies, the California Urban Future models, developed by Institute of Urban and Regional Development at UC Berkeley, employed the reduced-form logit regression to forecast eight types of land use conversion (Landis and Zhang, 1998). In Landis and Reilly’s study (2003), this approach was further modified into a binary land use model. In this study, the binary logistic regression model is utilized to explore the statistical relationship between transit rail and land transformation. Limited by the data availability, this regression analysis is conducted based on 2010 census block groups. Its purpose is to explore the driving forces of urban development and the role of transit expansion in the process of urban dispersion in Portland.
3.4.1 Dependent Variables

The dependent variable of this model is binary representing whether the block group has transitioned from non-urban to urban land use over the study period. In this study, the land use feature was calibrated based on the definition of 'urban area', which was developed by the Census Bureau during Census 2000. According to that definition, urban area typically refers to densely settled land in an urbanized area (UA) or an urban cluster, where "core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile" (US Census Bureau, 2000).

3.4.2 Independent Variables

A number of different factors - including transportation accessibility, network connectivity, distance to downtown and other employment centers, distance to highway, topography, and block size - are expected to impact urban land development (Reilly et al., 2009; CTOD, 2011). Meanwhile, according to the transportation and land use model shown in Figure 2-1 (Giuliano, 2004), the land use change is a direct result of accessibility. With a review to relevant literature, the independent variables of this study therefore focused on a set of accessibility measures. In detail, accesses to arterials, freeways, transit stations, CBD/city center, job opportunities, and other urban land were coded for this study using Arc GIS. What is noteworthy about these variables is that arterial refers to urban road with high-traffic volume, carrying traffic between collector roads and freeways or expressways, and between urban activity centers (Federal Highway Administration, 2013). Therefore, similar to freeways, arterials primarily improve the mobility of automobiles.
Besides accessibility indicators, physical and jurisdictional variables are introduced into this model. Firstly, topography is expected to influence urban development. CBGs in areas with more slopes or high slopes are anticipated to have lower development possibilities, as it is much more costly for construction and service provision in such areas than on the flat ground. Secondly, land covered by incorporated cities is assumed to be more likely to be developed, since area within the city limits is normally better linked to city services. By controlling part of these accessibility variables, physical and jurisdictional factors in the SPSS, the significance of transportation-related variables in influencing urban development and expansion in Portland, OR can then be identified through this model. Table 3-3 specifies the independent variables employed in the logistic model and Table 3-4 summarizes relevant data sources.
<table>
<thead>
<tr>
<th>Category</th>
<th>Variables</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>Access to arterials</td>
<td>The Euclidean distance from a CBG (census block group) centroid to the nearest arterial</td>
</tr>
<tr>
<td></td>
<td>Access to freeways</td>
<td>The Euclidean distance from a CBG centroid to the nearest freeway</td>
</tr>
<tr>
<td></td>
<td>Access to transit stations</td>
<td>The Euclidean distance from the CBG centroid to the nearest transit station</td>
</tr>
<tr>
<td></td>
<td>Transfer attribute</td>
<td>A dummy variable showing whether the nearest station from the CBG centroid is a transfer station</td>
</tr>
<tr>
<td></td>
<td>Access to CBD/city center</td>
<td>The Euclidean distance from the CBG centroid to city center</td>
</tr>
<tr>
<td></td>
<td>Access to regional centers</td>
<td>The Euclidean distance from the CBG centroid to the nearest regional center</td>
</tr>
<tr>
<td></td>
<td>Access to job opportunities</td>
<td>The number of jobs within 45 minutes auto travel from the CBG centroid</td>
</tr>
<tr>
<td></td>
<td>Access to other urban land</td>
<td>The percentage of neighboring CBGs that are defined as 'urban area'</td>
</tr>
<tr>
<td>Physical conditions</td>
<td>Slope</td>
<td>A dummy variable showing whether this CBG has a larger sloppy area than the mean or whether it has a major slope (over 41%)</td>
</tr>
<tr>
<td>Jurisdictional condition</td>
<td>Incorporated City</td>
<td>A dummy variable showing whether this CBG is within the incorporated cities</td>
</tr>
</tbody>
</table>
Table 3-4. Data Sources Used in the Binary Logistic Regression Analysis

<table>
<thead>
<tr>
<th>Variables</th>
<th>Dataset</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to arterials</td>
<td>Concept centers</td>
<td>Metro RLIS Discovery</td>
</tr>
<tr>
<td>Access to freeways</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to transit stations</td>
<td>Transit stations</td>
<td>Metro RLIS Discovery</td>
</tr>
<tr>
<td>Transfer attribute</td>
<td>Transit lines</td>
<td>Metro RLIS Discovery</td>
</tr>
<tr>
<td>Access to CBD/city center</td>
<td>Concept centers</td>
<td>Metro RLIS Discovery</td>
</tr>
<tr>
<td>Access to regional centers</td>
<td>Concept centers</td>
<td>Metro RLIS Discovery</td>
</tr>
<tr>
<td>Access to job opportunities</td>
<td>Destination accessibility</td>
<td>Smart Location Database</td>
</tr>
<tr>
<td>Access to other urban land</td>
<td>2010 Population</td>
<td>Metro RLIS Discovery</td>
</tr>
<tr>
<td>Slope</td>
<td>Slope, Oregon</td>
<td>Oregon Department of Forestry</td>
</tr>
<tr>
<td>Incorporated City</td>
<td>City Limits</td>
<td>Metro RLIS Discovery</td>
</tr>
</tbody>
</table>
CHAPTER 4
RAIL TRANSIT DEVELOPMENT AND URBAN GROWTH IN THE GREATER PORTLAND

The case of Portland is unique as the Metro regional government in the Greater Portland is an elected council. The Metro is in charge of growth management, tax collection, land use, and transportation planning for urban portions of three counties, which are Washington, Multnomah, and Clackamas counties. Under this state planning structure, urban growth boundaries have been enacted as a result of Land Conservation and Development Act of 1973 (Nelson & Land, 2009). These boundaries are set to control sprawl and restrict development outside of the designated area. The designated area within the boundaries is supposed to accommodate 20 years of development. However, how these boundaries are delineated can vary, largely depending on local planning. In Oregon, cities and counties primarily determine and amend the growth boundary based on their justification for local development, the involvement of the state lies in that it oversees compliance with the goal of growth management (Anderson, 1999).

In addition to growth boundaries, strong connections between transportation and land use planning, a bicycle and pedestrian plan, as well as a Transportation and Growth Management (TGM) Program, were further required by the Transportation Planning Rule in 1991 (Leo, 1998). The TGM program was specially established to encourage smart growth and multi-modal transportation by offering assistance and funding opportunities.

Besides, considering that it is municipality’s responsibility to do ultimate local-level zoning and execute the plan, the Metro government has provided guidelines about the methods for accommodating potential growth via the Regional Framework Plan
since 1995 (Metro, 2014). The Regional Framework Plan and the regional policies today are most descended from the 2040 Growth Concept.

4.1 An Overview of Light Rail Development in the Greater Portland

The light rail in Portland metropolitan area is constructed and run by TriMet, also known as Tri-County Metropolitan Transportation District of Oregon. With the 1980 Regional Transportation Plan supporting the development of transit lines, the construction of light rail system started in 1982. As presented in Table 4-1, the transit system in the Greater Portland has been developed and expanded in the recent decades. With two lines opened in 1980s and 1990s respectively, most MAX lines and the only WES line all opened in 2000s. By the analysis year 2010, all the existing lines opened.

After more than 20 years of development and expansion, the transit system in Portland links the city center with the surrounding suburbs. Meanwhile, as a result of incentives for transit development, Portland transit system came with progressive plans such as Portland Transit Mall, which are connected transit corridors across the center of downtown, and Fareless Square, which also known as ‘Free Rail Zone’. With the increasing accessibility between the central city and suburban areas, as well as the supporting land use plans, the transit system is expected to have some influences on the land use and development pattern in Portland.
Figure 4-1. The Map of MAX Transit Lines (Source: TriMet)
Table 4-1. History of Portland Transit System (Summarized from TriMet website information: http://trimet.org/about/history/index.htm)

<table>
<thead>
<tr>
<th>Segment description</th>
<th>Date opened</th>
<th>Line(s)</th>
<th>Termini</th>
<th>Stations</th>
<th>Length (mi)</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westside MAX Blue Line</td>
<td>September 12, 1998</td>
<td>MAX Blue</td>
<td>Hillsboro/City Center</td>
<td>20</td>
<td>17.6</td>
<td>May 1999 – September 2001</td>
</tr>
<tr>
<td>Airport MAX Red Line</td>
<td>September 10, 2001</td>
<td>MAX Red</td>
<td>Beaverton TC/Airport/City Center</td>
<td>4</td>
<td>5.6</td>
<td>May 1999 – September 2001</td>
</tr>
<tr>
<td>Interstate MAX Yellow Line</td>
<td>May 1, 2004</td>
<td>MAX Yellow</td>
<td>Expo Center/City Center</td>
<td>10</td>
<td>5.8</td>
<td>November 2000 – May 2004</td>
</tr>
<tr>
<td>I-205/Portland Mall MAX Green Line</td>
<td>September 12, 2009</td>
<td>MAX Green</td>
<td>Clackamas Town Center/City Center</td>
<td>20</td>
<td>8.3</td>
<td>February 2007 – September 2009</td>
</tr>
<tr>
<td>Portland–Milwaukie MAX Orange Line</td>
<td>September 12, 2015</td>
<td>MAX Orange</td>
<td>Union Station/Milwaukie</td>
<td>10</td>
<td>7.3</td>
<td>June 2011 – September 2015</td>
</tr>
</tbody>
</table>
4.2 Urban Growth in the Greater Portland

As shown in Figure 4-2, the Greater Portland region has undergone a significant expansion of built-up areas from 1990s to 2010s. With the majority of green fields within the urban growth boundaries being developed during the last two decades, population of the metro region has increased notably by more than 35%. Based on 2010 census, Portland was ranked the 23rd largest metro region in the US (Horowitz, 2012).

With a scrutiny of population and employment statistics in 1990 and 2010 at the census tract level (Table 4-2), the total population and employment in the metro region and the transit corridor were observed to grow incredibly by around 30%. Yet, interestingly, compared with the growth of the metro region, the population and employment at the transit corridor increased at a lower rate regardless of the transit expansion. Similarly, the population and employment density at the metro level also increased relatively faster than the ones at the transit corridor level. Additionally, a more intuitive result to emerge from the data is that the regional shares of both population and employment in the transit corridor have slightly decreased over this 20-year period, in spite of the absolute numbers have increased. This combination of descriptive findings suggests that the population and job growth outside the transit buffer of influence was greater than the areas directly affected by the transit. In contrast to the hypothesis that regional population dispersion is going to be positively influenced by transit development, concentrating towards transit lines, it can be preliminarily inferred from the descriptive analysis that the dispersion at the regional scale in this case may have a relatively weak relationship with the development and expansion of transit lines.
Although the regional share of population in the transit corridors has decreased by 2.84% during the study period, it is noteworthy that the regional share of population in census tracts with transfer stations has increased by 7.64%. Meanwhile, population around transfer stations grew at a rate of 47.42% from 1990 to 2010, which is higher than any growth rate mentioned in Table 4-2. It is possible that transit effect is greater at a more localized scale, in particular around transfer stations. On the one side, it can be explained by the efficient transit usage around transfer stations. On the other side, it can possibly be attributed to the network effect, as areas around transfer stations are influenced by more than one transit lines. Consequently, in Portland, rail transit may have a significant role at a smaller scale and this effect may increase as the transit network expands.
Figure 4-2. Urban Development in Portland Metropolitan Area at Years of 1992 and 2011 (Calibrated based on National Land Cover Database, http://www.mrlc.gov/)

Table 4-2. Population and Employment Growth in the Metro and the Transit Corridor of the Greater Portland

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1,323</td>
<td>798</td>
<td>886</td>
<td>628</td>
<td>67.0%</td>
<td>78.70%</td>
<td>4.42</td>
<td>2.67</td>
<td>7.52</td>
<td>4.53</td>
</tr>
<tr>
<td>1,812</td>
<td>1,038</td>
<td>1,180</td>
<td>805</td>
<td>65.1%</td>
<td>77.54%</td>
<td>6.06</td>
<td>3.47</td>
<td>10.29</td>
<td>5.89</td>
</tr>
<tr>
<td>36.99%</td>
<td>30.09%</td>
<td>33.11%</td>
<td>28.17%</td>
<td>-2.84%</td>
<td>-1.48%</td>
<td>37.01%</td>
<td>30.09%</td>
<td>36.85%</td>
<td>29.94%</td>
</tr>
</tbody>
</table>
4.3 Spatial Patterns of Urban Growth at Regional and Transit Corridor Levels

While the descriptive statistics tell a mixed story about urban growth in the Portland metropolitan area, this section further investigates the spatial distribution of the changes occurred in the study area. Regionally, a hot spot analysis was conducted to examine spatial clusters of population and employment and to show how the spatial growth has evolved with the transit development over the study period (Figure 4-3 and Figure 4-4). As a large band size tends to overshadow the difference of clustering in this case, this analysis was run on a band width of 0.5 miles. On top of the hot spot analysis, a t-test was applied to compare the density value of each tract in the transit shed with the average density of tracts outside the transit corridor. Those significantly dense tracts (with a 90% confidence interval) were highlighted in the map of each year (Figure 4-5 and Figure 4-6). As has been suggested by the statistics, the growth out of the transit corridor was more significant than the one inside the transit shed during the study period. This t-test, from another perspective, is to see whether the transit lines have remained important in attracting population and employment, and contributing to an agglomeration along the transit lines, compared with the areas out of the transit corridor.

In a general term, no significant low-density clusters were shown in the Figure 4-3 and Figure 4-4, indicating that employment and population in areas other than the high-density tracts have been constantly homogeneous. Concerning population clusters, it can be seen from Figure 4-3 that population in 1990 were primarily clustered around the City Center and inner-city areas – Eastside of the Willamette River. With the notable transit expansion, new clusters shown in 2010 were further away from the central city. One cluster appeared to be on the far east side while another on the far west side. Nonetheless, one interesting result to emerge from the map is that these new
clusters away from the city center are located near the expanded transit line. As all clusters shown in Figure 4-3 and 4-4 are within the transit corridor, such clusters can possibly be attributed to the effect of transit development, which increases accessibility to the outer urban areas and stimulates concentrations towards the light rail. However, it is also possible that original main clusters have been replaced by smaller clusters as the growth pattern has become more disperse. As in Figure 4-3, a large proportion of previous concentrations on the east side of the Willamette River no longer showed in the 2010 population cluster map.

Compared with the population clusters, employment clusters in 1990 were more focused on the central city, suggesting a monocentric employment pattern in the metro region. By 2010, while the original employment cluster of metro Portland has remained largely concentrated in the downtown Portland, new clusters emerged in other parts of the inner city. For instance, one new cluster came up in the northeast of the center city, where is a part of the Lloyd District. Lloyd District has been designated as a commercial neighborhood and it was also partially included in the Tri-Met’s Fareless Square. Since all the employment clusters remained in the transit shed, this movement of clusters could reflect the changes of locational choices as an effect of transit expansion.

With a specific look at census tracts in the transit corridor, Figure 4-5 and Figure 4-6 further show a process of how population and employment agglomerate along the transit lines over the study period. These maps are revealing in several ways. First, they indicate that an increasing number of tracts, inside the transit corridor, have become significantly denser. Second, those originally dense tracts have remained ‘dense’ throughout the study years. During the time without any transit line, the significantly
dense tracts were basically in the center and east side of the city. In 1990, several tracts in the due west and southwest side turned into denser. However, it cannot be simply explained by the light rail development, as only eastside MAX blue line had been developed by then. A great proportion of tracts within the transit corridor became denser between 1990 and 2010, which include tracts to the most east and the most west of the corridor. As this is the time period that the Portland rail transit system has undergone the greatest expansion, such population growth could be explained as the transit impact on urban form. Yet, considering the 1990 scenario, it is also possible that the transit lines were planned after the growth, with a purpose to serve the dense areas, during this twenty-year period.

Overall, these results suggest an outward movement of clusters in the metro and confirm a progress of agglomeration within the transit corridor. Although these analyses cannot directly indicate the contributing factors behind such spatial change and growth, these preliminary findings on urban growth and spatial distribution in the metro Portland will serve as a base for the following analyses.
Figure 4-3. Hot Spot Analysis – Population Clusters in 1990 (Left) and 2010 (Right)

Figure 4-4. Hot Spot Analysis – Employment Clusters in 1990 (Left) and 2010 (Right)
Figure 4-5. Population Agglomeration along the Transit Lines in the Metro Portland

Figure 4-6. Employment Agglomeration along the Transit Lines in the Metro Portland
CHAPTER 5
RAIL TRANSIT AND DENSITY

Through descriptive statistics and spatial analyses presented in the last chapter, the findings showed a definite increase in population and a relative growth of high density clusters in the region and in the transit corridor. These results further identified a physical agglomeration of population and employment along the transit line from 1990 to 2010. While these analyses presented shifts of the spatial patterns, they primarily failed to prove that the increasing number of dense clusters, or density dispersal, is related to the transit project at either a regional or corridor level. Meanwhile, the high density clusters and agglomerations could be a result of densification in tracts, as influenced by transit lines. An alternative explanation can be decentralization, in which case population move from the densest area to nearby tracts. Whether transit development can effectively increase urban density remains uncertain. In addition, another limitation lies in that these analyses were unable to indicate the scale and magnitude of density variations. Considering abovementioned flaws, in this chapter, a simple multivariate regression model was developed on the census block group scale to check the significance of transit-related indicators, and further to estimate the local and regional influence of transit lines on the variations of population density.

5.1 Model Specification

The multivariate regression model was run at both local and regional scales in the years of 1990 and 2010 respectively, to identify the relationship between population density and the accessibility to transit stations vs. transfer attribute of the nearest transit station. Besides two main transit indicators, CBD accessibility and geological slope
were also introduced (Figure 5-1). All these theoretically important variables were entered into the multivariate model, the results are analyzed and compared as follows.

\[
\text{Population Density} = \frac{A + B_1 \times\text{Access to Transit Stations} + B_2 \times\text{Transfer Attribute} + B_3 \times\text{Access to CBD} + B_4 \times\text{Slope}}{(\text{pop/ acres})}\quad(1990\ & 2010)
\]

Figure 5-1. Model Equation for the Multivariate Regression Model

5.2 Model Results

Table 5-1 below summarizes four population density models (1990 metro region scenario, 2010 metro region scenario, 1990 TriMet transit corridor scenario, and 2010 TriMet transit corridor scenario). These results allow comparisons of different years as well as on different scales. Due to the data fusion of many measurements with different dimensions, unstandardized coefficients vary dramatically and standardized coefficients were presented in Table 5-1 for the comparison purpose. Overall, the model explained the most variations, which is 37.7%, in 2010 at the transit corridor scale for population density. Except the 2010 transit corridor model, other model reports indicated relatively poor likelihood of statistical significance. The poor performance may partly be explained by the absence of many other core indicators that have influence on the dependent variable, for example, land use variables, job market connectivity and so on. In spite of the model significance, what is common to these four models is that both accessibility to CBD and geographic slope significantly explained the variations of population density over time. It can be inferred that the CBD in Portland has remained important and vibrant in the polycentric planning context.
### Table 5-1. Multivariate Model Results for Population Density in 1990 and 2010

<table>
<thead>
<tr>
<th></th>
<th>1990 Unstandardized Coefficients</th>
<th>Std. Error</th>
<th>1990 Standardized Coefficients</th>
<th>Sig.</th>
<th>2010 Unstandardized Coefficients</th>
<th>Std. Error</th>
<th>2010 Standardized Coefficients</th>
<th>Sig.</th>
<th>Adjusted R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metro Region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to CBD</td>
<td>-20.292</td>
<td>58.481</td>
<td>-0.029</td>
<td>0.048*</td>
<td>-7.947</td>
<td>4.033</td>
<td>-0.080</td>
<td>0.049*</td>
<td></td>
</tr>
<tr>
<td>Access to transit stations</td>
<td>6.502</td>
<td>57.892</td>
<td>0.007</td>
<td>0.711</td>
<td>-163.968</td>
<td>91.032</td>
<td>-0.068</td>
<td>0.072</td>
<td></td>
</tr>
<tr>
<td>Transfer attribute</td>
<td>283.527</td>
<td>606.044</td>
<td>0.026</td>
<td>0.540</td>
<td>165.941</td>
<td>63.650</td>
<td>0.096</td>
<td>0.009*</td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>-581.640</td>
<td>701.166</td>
<td>-0.192</td>
<td>0.040*</td>
<td>0.133</td>
<td>-429.864</td>
<td>122.536</td>
<td>-0.119*</td>
<td>0.286</td>
</tr>
<tr>
<td><strong>Transit Corridor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to CBD</td>
<td>-53.271</td>
<td>19.767</td>
<td>-0.168</td>
<td>0.033*</td>
<td>-13.838</td>
<td>4.282</td>
<td>-0.151</td>
<td>0.001*</td>
<td></td>
</tr>
<tr>
<td>Access to transit stations</td>
<td>5.618</td>
<td>5.804</td>
<td>0.098</td>
<td>0.108</td>
<td>-218.301</td>
<td>91.275</td>
<td>-0.103</td>
<td>0.017*</td>
<td></td>
</tr>
<tr>
<td>Transfer attribute</td>
<td>80.940</td>
<td>101.412</td>
<td>0.050</td>
<td>0.199</td>
<td>116.957</td>
<td>57.865</td>
<td>0.084</td>
<td>0.044*</td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>-97.738</td>
<td>75.853</td>
<td>-0.130</td>
<td>0.031*</td>
<td>0.215</td>
<td>-491.961</td>
<td>118.661</td>
<td>-0.159*</td>
<td>0.377</td>
</tr>
</tbody>
</table>
Comparatively speaking, the 2010 models, with a relatively higher adjusted $R^2$, explained more variations in population density than 1990 models. These results are likely to be related to the number of significant variables in the models. The number of statistically significant variables increased from two to four from 1990 to 2010, including two more transit variables. In 1990 models, transit-related variables were statistically insignificant and ‘the access to transit stations’ had a coefficient sign contrary to expectations. A possible explanation derived from previous studies might be that four years after opening are still too short for urban form and land use to respond to the transit development. In reviewing relevant literature around the same study period, Lewis-Workman and Brod (1997) similarly found a coefficient sign for the indicator of ‘distance of home from station’ opposite to their hypotheses, when they studied residential benefits of transit accessibility in Portland. Lewis-Workman and Brod’s study (1997) concluded with a weak relationship. In addition, another study focused on the relationship between property values and transit stations in Portland (Al-Mosaind et al., 1993) found that property value premium is not significantly related to the station proximity. Besides, this result is in agreement with findings obtained by the previous spatial analysis (Figure 4-5). When only east half of the blue MAX line was in operation in 1990, population started to agglomerate on the due west and southwest side of the corridor, which can partly be attributed to the arrival of high-tech companies in Hillsboro, OR in the 1980s (HillsboroOregon, 2015). To some extent, population distribution is not sufficiently associated with the 1990 transit line in space. In 2010, with four transit lines in service, the transit-related indicators became significant in each iteration.
Turning now to the transit impacts on different scales, both access to transit stations and transfer attribute showed great impacts on population density. The significance values for these transit-related indicators have decreased dramatically from 1990 to 2010. As suggested by coefficients in the 2010 transit corridor model, both transit measures appear to be significant, while transit accessibility tends to have a stronger impact on density. Unlike the transit corridor model, only one of the transit-related variables, transfer attribute, has a far-reaching influence on population distribution as shown in the regional model. Taken together, these results suggest that population distribution in 2010 was concentrated around the station areas at a local scale; while, regionally, population were more focused on the areas particularly around transfer stations.

Figure 5-2. Designated Centers in Metro’s Regional Framework Plan

Such density dispersal can be a result of transit expansion, however, it can also be influenced by the metro’s planning policies. For example, based on the Metro’s
Regional Framework Plan, several programs and plans, such as Urban Growth Management Functional Plan (UGMFP), station areas rezoning and Regional Transportation Functional Plan, have been carried out to encourage denser growth around city center, regional centers, town centers and station areas (Figure 5-2). In detail, the UGMFP sets a minimum density requirement at 80% of the highest density of any areas zoned for residential land (Metro, 2014b). Additionally, the TOD program regulates that funding are available for development within 0.25 miles of high capacity transit stations, which include most transfer stations. By providing funding and other incentives, the Metro facilitates high density development and improvements of transit and pedestrian facilities around the station areas (Metro, 2014a). Transfer stations themselves are defined as centers in Metro’s regional plan, meanwhile, a number of town centers and regional centers selected to locate near transfer stations. In such a context, high density around station areas could be a combined effect of policies and transit expansion. It would be rather difficult to distinguish the regional policy effects from the impacts of transit on population dispersal.

Noticeably, although the transit-related indicators were statistically significant in the 2010 models, the absolute values of standardized coefficients for transit-related indicators were relatively small. At the metro level, transit influence was smaller than the variable of ‘slope’; at the transit corridor level, transit impact was less significant than both variables of ‘slope’ and ‘access to CBD’.

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CHAPTER 6
RAIL TRANSIT AND URBAN SPRAWL

As was pointed out in the multivariate models, rail transit development is positively associated with density, especially around transfer station areas, under certain conditions. While rail expansion can possibly facilitate development along transit lines, will it also cause development on vacant land? In theory, transit expansion is also a form of transportation improvement. The development of rail transit increases access to employment centers and reduces the non-financial cost of living out of the inner city. Cities, therefore, are able to expand further away from downtown than before, as a result of the decentralizing effect (Giuliano, 2004). On the other hand, mass transit is frequently referred as a ‘sprawl-repair’ strategy because of its role in providing an alternative mode of transportation to automobile commuters (Walker, 2010). By diverting auto users to public transportation, rail transit systems are often developed with the purpose to reduce auto traffic and curb further sprawl. To identify the role of transit development in Portland metropolitan area, a binary logistic regression model on land transformation was developed in this chapter. This first section of this chapter discusses the model results and explores the driving forces of urbanization. Following that, the research question on whether transit significantly propels the process of urban land transformation in the study region and other possibilities about the relationship between rail transit and urban growth pattern are further discussed.

6.1 Model Specification

The binary logistic regression model was developed based on the metro region land use in the years of 1990 and 2010. The dependent variable is the
binary land transition of census block group in the Portland metropolitan area from 'non-urban' to 'urban'. This model seeks to investigate how accessibility factors, physical conditions, and jurisdictional variables are related to the urbanization process. The transit indicator in this model refers specifically to ‘access to transit stations’. However, among all the indicators, the variable of ‘access to job opportunities' is significantly correlated with ‘access to CBD'. Hence, the variable of ‘access to job opportunities' was excluded from the final model. The final model equation was shown in Figure 6-1.

$$\text{logit}(P|\text{Land transformation}) = A + B_1 \times \text{Access to Arterials} + B_2 \times \text{Access to Freeways} + B_3 \times \text{Access to Transit Stations} + B_4 \times \text{Access to CBD} + B_5 \times \text{Access to regional centers} + B_6 \times \text{Access to other urban land} + B_7 \times \text{Slope} + B_8 \times \text{Incorporated City} \quad (2010)$$

Figure 6-1. Model Equation for the Binary Logistic Regression Analysis

6.2 Model Results

Table 6-1. Binary Logistic Model Results for Land Transformation between 1990 and 2010

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Standard Errors</th>
<th>Odds Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to CBD</td>
<td>0.000</td>
<td>0.000</td>
<td>1.000 *</td>
</tr>
<tr>
<td>Access to regional centers</td>
<td>-0.011</td>
<td>0.034</td>
<td>0.988 *</td>
</tr>
<tr>
<td>Access to freeways</td>
<td>-0.125</td>
<td>0.069</td>
<td>0.883 *</td>
</tr>
<tr>
<td>Access to arterials</td>
<td>-0.942</td>
<td>0.712</td>
<td>0.390</td>
</tr>
<tr>
<td>Access to transit stations</td>
<td>0.538</td>
<td>0.486</td>
<td>1.713</td>
</tr>
<tr>
<td>Urban neighborhood</td>
<td>-0.012</td>
<td>0.008</td>
<td>0.989</td>
</tr>
<tr>
<td>Incorporated feature (No)</td>
<td>-0.236</td>
<td>0.824</td>
<td>0.789</td>
</tr>
<tr>
<td>Slope(Flat)</td>
<td>1.416</td>
<td>1.042</td>
<td>4.122 *</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.756</td>
<td>1.486</td>
<td>0.173</td>
</tr>
</tbody>
</table>

Overall % correct 90.10%
According to Hosmer and Lemeshow Test for goodness of fit, the significance measure of this logistic model is 0.460, larger than 0.05, showing that the data fits the model well. Four variables are significant at 0.05 with coefficients in the expected direction. For logistic models, exploring odds ratios is an intuitive approach to learn about the model results. Odds ratio is generated by exponentiating the coefficient ‘B’. It indicates how much the odds grows multiplicatively with 1 unit of change on the variable of interest. As for the categorical variable, they can be directly viewed as odds ratios between groups. In general, an odds ratio around 1 suggests no land transformation. An odds ratio over 1 indicates a higher possibility of urbanization with 1 unit of change; an odds ratio less than 1 shows a lower likelihood of rural-urban transition with 1 unit of change. For example, according to the model results shown in Table 6-1, flat block groups in Portland were more than four times as likely to be ‘urban’ as block groups with major geological slopes.

It is not surprising that CBD and regional center accessibility were significantly associated with the land transformation process. This result is in line with prior studies, showing that destination or employment accessibility is the central influence on locational choice and land use (Waddell, 1996; Kitamura, 2001; Ewing & Cervero, 2010). Comparing the odds ratios for access to CBD and access to regional centers, it is interesting to find that both CBD and regional center accessibility had a very limited influence on possibility of land transformation; block groups close to regional centers had a slight higher probability to become ‘urban’. One possible explanation for this could be that
while land around centers had mainly undergone the urbanization process before 1990, newly urbanized block groups were mostly at the city periphery away from centers. Consequently, considering the available land for development, the influence of regional centers on rural-urban transformation is possibly decreasing over the years. This result is consistent with the previous study on Bay area (Reilly et al., 2009), which suggested that the connection between CBD accessibility and the likelihood of urbanization has weakened from 1948 to 2004 in Silicon Valley, California.

The most striking result to emerge from the model is that highway accessibility had a strong influence on the possibility of becoming ‘urban’. While controlling for other variables in the model, each additional kilometer a block group was from the nearest highway means that becoming ‘urban’ was only 88% as likely. Consequently, highway accessibility is one of the most statistically significant forces that drive land transformation.

Meanwhile, another notable result to emerge from the model is the odds ratio of ‘access to arterials’ was relatively small compared with other variables in the model, showing that one additional kilometer from arterials led to about 61% less probability to be urban. Conversely, the transit indicator, ‘access to transit station’, has been found to have a negative impact on the probability of being urban. Nevertheless, none of these two relationships were found to be statistically significant. Besides, urban neighborhoods, or access to other urban land, were negatively related to the possibility of becoming ‘urban’. In other words, a given block group with a large proportion of urban neighborhoods tended to be less likely to be ‘urban’. However, similar to indicators of arterial and
transit accessibility, the relation between urban neighborhoods and land
transformation again was not identified as significant, this result only suggests a
potential risk of leapfrog development in Portland, which still needs to be further
scrutinized.

Overall, results of this binary logistic regression model indicate that
highway accessibility is the primary factor that increases the possibility of
becoming ‘urban land’, namely, the driving force of urbanization. Among these
factors, highway accessibility plays a critical role in the urban land transformation
in terms of the significance and magnitude of its influence. Transit, however, is
not in this list, after about 24 years of service. Urban growth of metropolitan
Portland is largely determined by the provision of roadway infrastructure.
Consequently, urban dispersion is mostly geared towards auto vehicles.

6.3 Discussion about the Relationship between Rail Transit and Urban
Sprawl in the Metro Portland

The results of the binary logistic regression model suggest that the
decentralizing effect, in the form of urbanization, brought by the transit
development in Portland is rather insignificant. Urban sprawl is mainly influenced
by the development of urban road infrastructure. As rail transit has not
aggravated urban sprawl in the metro region, another important question lies in
whether rail development is an effective strategy to control regional sprawl.
Based on what occurred in Portland metro, the answer is probably no.

According to the analysis done in Chapter 4, the area of built-up land in
the metro region has undergone a tremendous dispersion from 1992 to 2011
(Figure 4-2). In the meantime, population has also been continuously dispersing
over time. The population growth outside the transit corridor has been greater
than the increase inside. More importantly, according to Cox (2013), over 90% of the population growth in the metropolitan area took place outside the five-mile radius from Portland City Hall from 2000 to 2010. The regional share of Multnomah County (historical core) population to the metro’s population has dropped from two thirds to one third during 1930 and 2010 (Cox, 2013).

![Figure 6-2. Transit Mode Share in Metropolitan Portland (Employment Access: 1980 – 2010; Cox, 2013)](image)

While urban sprawl has been in full swing in the last two decades, transit mode share for working trips has fallen by around 25% compared with the figure in 1980 (Figure 6-2). In spite of a slight increase after 1990, the percentage has remained low compared with the pre-transit time and the number was quite close to the national average of 5%. At the same time, the congestion problem in Portland got intensified. The Annual Mobility Report 2011 developed by the Texas A&M Texas Transportation Institute ranked Portland metropolitan area has the 6th worst traffic congestion among major metropolitan areas in the nation (Schrank et al., 2012). Comparatively, it was once ranked the 39th in 1982.
Taken together, it seems that Portland metro area has continued to sprawl massively after the opening of transit lines. The rail transit expansion itself did not make the public transportation more appealing to daily commuters. As an anti-sprawl planning strategy, the transit development probably fails to directly divert car users to the transit system or alter the calculus of travel. The process of urban land transformation in Portland, to a great extent, has been dominated by the auto travel and the spatial distribution of road facilities; while transit during the study period only plays a minor role in this process, which has neither aggravated nor restrained the sprawl of Portland metro region.
CHAPTER 7
CONCLUSION

Through an integrated approach of case study, quantitative modeling and qualitative analysis, this study investigated the impacts of rail transit development on urban form and urban growth pattern in Portland metropolitan area. Along with the impact analysis, this study assessed the effectiveness of transit expansion as a regional strategy to stimulate dense development and curb urban sprawl. By cross-time and cross-scale comparisons, the findings of this study enhanced our understanding on the Portland growth pattern and the aggressive land use and transportation planning scheme in Portland, OR. This concluding chapter begins by summarizing key findings that emerge from this study and discussing implication for planning practices. It goes on to suggest the limitations of this study. At the end of this chapter are recommendations for further research work.

7.1 Summary of Research Findings

Historically, it has been considered as a conundrum to discern the effects of transportation investments on land use and urban growth. Some of the previous studies reached opposite conclusions on the same case. Unsurprisingly, the results of this study are rather mixed.

Descriptive and spatial analyses indicate a general population increase in both the transit corridor and the metro region and a gradual agglomeration of population along the transit corridor from 1990 to 2010. However, regionally, the study area has become less concentrated. Firstly, the built-up land has been sprawling close to the urban growth boundary. Secondly, the number of high density tracts in the region has
decreased and the clusters of population have become more disperse to further west and further east. Thirdly, the population growth outside the transit corridor tended to be more significant than the increase inside the corridor.

With suggestions provided by the descriptive and spatial analyses, the multivariate regression models looked at the impacts of transit development at both the corridor and the metro region levels in the years of 1990 and 2010. In 1990 when there was only one line in operation, the models attribute the most variations of population density in the study area to city center accessibility and geological slope, very few to rail transit. However, in the models of 2010, when there were four lines in service, the results show that transit-related variables are significantly associated with the population density locally and regionally. In addition, as it has been hypothesized, the influence of transit variables at the transit corridor level is much greater than the one at the regional level, in terms of the number of significant variables and the magnitude of corresponding coefficients. These results suggest that, firstly, rail transit has a growing impact on urban form with the transit expansion during the study period; secondly, the effects of rail expansion on density are quite localized, with more population around stations; thirdly, transfer stations even have a positive association with the regional density dispersal in this case, which has not been described in previous studies.

When the results of the multivariate regression models suggest that rail transit plays a positive role in facilitating compact growth around the station areas, the effect of transit expansion on sprawl is relatively more inconclusive. According to results of the binary logistic regression model, urbanization over the study period is primarily driven by the highway accessibility. The effect of transit expansion on rural-urban
transformation is relatively insignificant. When transit development has not exacerbated the issue of sprawl, the decreasing share of commuters by transit, compared with figures in 1980, seems to suggest that transit expansion as a regional strategy is not enough to alter commuters’ travel behavior and further curb the sprawl. As a result, it can be inferred that the impact of rail expansion itself on urban sprawl is minimal.

7.2 Policy Implications

Returning to the question posed at the beginning of this study, the aim of this investigation is to assess the efficacy of transit expansion as one widely adopted regional anti-sprawl planning strategy. Based on the points elaborated in the previous chapters, this section focuses on a couple of issues that would be of particular interest to planners and policy makers.

Firstly, many MPOs have control over the transportation planning funding but with few initiatives on other planning tools. For MPOs, the possibility of using the sole power in hand to achieve the goals of compact growth and sprawl control is quite attempting. Although this study revealed a positive role for rail transit development in promoting denser growth, especially around station areas, this finding should be interpreted and generalized cautiously due to the uniqueness of Portland metropolitan area. Portland metro region has arguably one of the most aggressive regional policy structures to support transit development and spur growth around centers and transit stations areas. Within such regional policy structure, Portland is expected to show greater changes in density than other metropolitan regions. This study did not rule out the land use strategies that were combined with transportation planning. The conclusion reached by this study can be greatly influenced by the Portland’s regional incentive framework. With less support on land use, it can be a completely different story. In
Chicago and Cleveland, for example, due to less incentives and high land cost in downtown areas, the transit improvement generated minimal impacts on urban form and land use (Knight and Trygg, 1977). Therefore, learning from the case of Portland, regional planning should not be merely confined to transportation improvements. Other urban policies, such as station area rezoning, tax abatements and provision of project financing, have to be closely coordinated with the improvements of rail transit in order to see the desired positive impacts.

Secondly, though the improvements of transit system, to some extent, densified the station areas, its anti-sprawl effects are rather disappointing. As a regional strategy, it failed to increase the proportion of commuters by transit and the metro region continued to sprawl over the study period. The possible reason for this is possibly that the low cost of driving and parking was not well addressed. When rail transit system and station areas were developed vigorously, the car mode share in Portland remained at a high level; congestion became worse; roadway capacities, such as I-205, were constantly expanded. Consequently, auto use and car-supportive infrastructure, as ever, dominate the growth pattern. As suggested by this case, investing in rail transit solely is not enough, a more important role of planning is to do with the changing of auto-supportive environment, in order for the objective of sprawl mitigation to realize. This notion is consistent with those land use and transportation researchers (Giuliano, 2004; Shoup, 2005) who are in agreement with that curtailing incentives for auto-dependent development and for driving is a more effective approach to control growth and divert commuters away from cars.
Taken together, this study generally suggests that the improvement on rail transit system is more likely to facilitate rather than causing development. Despite the fact that transit development may contribute to the change of urban form, the transit system itself will have little impacts on the urban structure without the support of complementary policies. Hence, transit planning has to be closely integrated with land use policies, governmental incentives, regional economic context, and so on to ensure the success of this regional strategy, in which the positive effects worth the heavy cost of such plans. Portland metro region seems to be on a right track of planning that combines transportation planning with land use planning, and it already triggered the positive impacts of the planning strategy on urban density. However, more work has to be done in order to truly control the ongoing sprawling process.

7.3 Limitations of This Study

Despite that this study reached some immediate conclusions, several limitations have to be acknowledged regarding the present research.

Firstly, there are several issues that may lead to analysis errors for this study. When calculating population density, water and mountainous areas were included. It resulted in a few low-density tracts with significant geological features, which may not truly reflect the density by land. Besides, as metro region shares a different boundary with block groups, some block groups were split by the metro boundary. Those incomplete periphery block groups were excluded from the model before the accessibility measures were calculated. With fewer periphery block groups, the models developed in this study could be more biased towards the central city. In addition, all accessibility variables measured the distance between the geometric centroid of each block group to destinations. Without considering the spatial distribution of the population
inside the block group, this variable may not necessarily reflect the accessibility perceived by residents and daily commuters. These factors could be sources of errors that influence the stability of models.

Secondly, while the most analyses conducted in this study are based on census block groups, this scale of analysis unit is probably too broad to identify the shifts of growth dynamics. Given that the population density changes in this case are shown to be granular and urban development further expands, it is very likely that the study area has block-to-block, even point-to-point, changes with new growth. The block group data was used in this study, due to its higher analysis resolution compared to tract-level data and its ease to be processed when compared with raster input. However, the block group geographies change over the study period, it directly led to analysis errors in the process of identifying block groups that have transitioned from "non-urban" to "urban" in the study area between 1990 and 2010.

Thirdly, although the models in this study identified a few significant relations between independent and dependent variables, this study is unable to suggest the direction of causality. These results must be interpreted with caution, and they doubtlessly need further exploration. For instance, in terms of the relation between transit expansion and density, the increase of density can be a result of transit expansion. However, another possibility is that influenced by the historic city pattern, the population clustered in downtown areas long before the introduction of rail transit, transit lines were planned to serve population clustered in these areas. No certain conclusion can be drawn regarding this.
Fourthly, although this study confirmed that the sprawl in Portland metro region has increased during the study period, the rate of the increase has not been checked. It is likely that the increase rate has decelerated, with the expansion of transit network. Besides, considering that congestion in a lot of cases is quite localized due to crashes on the road and the poor design of roadways, the congestion ranking developed by the Texas A&M Texas Transportation Institute could be relatively weak to suggest the aggravated regional sprawl.

Fifthly, considering that either urban form or land use is a combined effect of all the evolutionary forces at works, it is impossible to sort out the actual influence of the transit development by controlling a limited number of non-transit factors. As has been pointed out in the previous chapters, in Portland, regional policy framework has a great impact on the formation of urban structure. Nonetheless, this study failed to isolate the transit effect from the policy impacts. In reality, on top of policy environment, demographic change, institutional capacity, alternative transportation infrastructure improvement, transportation network design, availability of developable land, technology development and many other factors have been more or less influencing the urban structure. Knight and Trygg (1977) summarized some of the potential factors influencing land use impacts in Figure 7-1. The complexity of the relations among urban structure and influencing forces makes it a challenging task to separate out the real impact of the transit facility from all other confounding factors.
7.4 Recommendations for Further Research

Based on a reflection of current study, many questions have been thrown up in need of further investigation.

Firstly, on the basis of this study, further work can be done to improve on methods and findings by narrowing down the analysis unit and controlling more variables directly for the formation of urban structure. In terms of transportation variables, the role of network quality and alternative bus service should be further controlled. As for transit-related independent variables, the model can be enhanced by accounting for transit service frequency and service quality, which tend to be important in influencing the commuters’ preference and further affecting land use change.
Besides, it is recommended to apply locally weighted regression and concentrate on the investigation of local variation, while this study simply assumes a global relationship between the transit facility and urban density.

Secondly, further studies can be carried out to identify the transit catchment area with greater transit influence. While TOD projects take full advantage of transit benefits within a walkable distance (normally less than half mile), this study suggests that the transit influence remains significant in a two-mile buffer. Nonetheless, regional authorities tend to expect a wider coverage of transit influence, for example, Los Angeles County Metropolitan Transportation Authority is expecting density increase within three miles of their planned stations. Identifying the transit catchment area will better inform planning decision-making and objective setting. It will also help to maximize the benefits of transit investments by initiating corresponding policy schemes.

Thirdly, in terms of transportation and land use modelling, further research can focus on multi-level models. More localized models can be developed to identify the role of transit development. Based on this study, it is possible that transit usage is more efficient at a smaller scale, especially around transit sheds. In the meanwhile, future research could look into models estimating marginal effects, which allow to separate out the effect of each variable associated with the change of population and land use. By breaking out the marginal effects, the impacts of the transit facility on urban growth can be better explained.

Fourthly, the complex and dynamic relations among all influencing factors and urban structure makes it hard to attribute the observed change and identify the role of a particular factor. On top of that, another aspect that perplexes this type of studies is the
length of analysis period. As suggested by the findings, four years are too short for the market in Portland to respond to the transit development. A longer study period is required to allow the effects to take place. However, many influencing factors will change in the long run and more factors have to be added during the study period. All these make a comprehensive land use impact model difficult and also make the determination of the role of transit system challenging. This study, as well as many previous land use research, is limited to “drawing inferences by looking at a handful of time slices using less-than-complete data” (Cervero and Landis, 1997, p. 312). Therefore, considerably more work will need to be done regarding the development of an integrated transportation-and-land-use model, in which the long-term evolution of urban structure can be traced in a controlled setting (Badoe and Miller, 2000). As an integrated urban model takes all major components and their interactions within the system into account, it not only helps to figure out the role of rail transit in urban growth, but only assists the analysis and forecast of land use changes.
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BIOGRAPHICAL SKETCH

Xinyuan Yang grew up in the historic city of Suzhou, China, and witnessed the rapid development and urbanization of Suzhou. With the interest in city-development issues, Xinyuan earned a Bachelor of Engineering in urban planning and design at Xi’an Jiaotong-Liverpool University, China and a Bachelor of Arts (with Honors) in civic design from University of Liverpool, UK. Xinyuan pursued a Master of Urban and Regional Planning degree at University of Florida to further explore urban issues specifically related to the internal relationship between transportation development and urban growth. Xinyuan continues to develop her planning knowledge and planning skills in order to become a professional planner that makes cities better places to live.