The Impact of Light Rail Transit-Oriented Development on Residential Property Value in Seattle, WA

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Abstract

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The study seeks to investigate the impact of transit-oriented development (TOD) on residential property values using the case of Link light rail TOD in Seattle. While many previous studies decompose TOD impact into constituent parts, the study captures the integrated influence of TOD. Hedonic pricing method is employed and time-series analysis is conducted for three selected light rail station areas. Dummy variables are designed to reflect TOD proximity and relevant structural characteristics, locational conditions, as well as social-economic attributes are identified and controlled in regression models. Results demonstrate that TOD impact is different across time periods. In pre and during construction periods, TOD does not have statistical significant influence on the prices of residential properties; in after-construction period, TOD has significant positive impact on values of residential properties that are located within 0.25-0.50 mile from the light rail station.

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CHAPTER 1 INTRODUCTION

Over the past decades, a growing number of communities have adopted Transit-Oriented Development (TOD) strategy to help revitalize American cities. TOD is designed typically for areas centered with a transit station, in order to maximum accessibility and utility of the public transport services.

Certain design and management principals are employed, giving TOD specific characteristics, such as high density, high degree of mixed-use, non-motorized friendly networks design, and high level of transit service (Dittmar and Ohland, 2004). Because of the unique characteristics, TOD has great influences on its surrounding areas. It is estimated that at an individual station, TOD can increase ridership by 20% to 40%, and up to 5% overall at the regional level (Arrington, 2005). Locations next to transit can enjoy increases in land values of over 50% in comparison to locations away from transit stops (City of Winnipeg, 2011).

Based on the kind of transit service that generates the development, TOD can be classified into different transit types, including rapid transit TOD, railway TOD, and light rail TOD. In the late 18^{th} century, light rail transit systems were opened in seven U.S. and four Canadian cities. Since then, light rail transit has been popular being proposed for large and medium-sized metropolitan areas (Black, 1993). With the increase of light rail construction projects, TOD around light rail transit is increasingly becoming a standard for the future of TOD in United States. Seattle's light rail project, the Link Light Rail was initiated in 1996, two lines of which are operated in 2009 including Tacoma Link, and Central Link. Along with the project, station area plans are conducted and employed to neighborhoods adjacent to light rail stations. New TOD neighborhoods have formed gradually around these light rail stations.

It is perhaps the right time to investigate the benefits brought by light rail TOD because a lot of new projects are underway and huge amount of efforts are putting in by local governments and policy makers. This paper seeks to estimate the capitalization of light rail TOD on residential properties, which would be beneficial for decision makers from local governments, real estate companies, and other related agencies to make better financial choices, as well as for the public to gain a better understanding of what changes TOD can bring to their daily lives.

The study is structured as follows. First, relevant literature is reviewed. Price effects of TOD related characteristics and other factors affecting property value, as well as previous analysis methods are compared and summarized. Research question and hypothesis, as well as conceptual models are then demonstrated in the methodology section. Hedonic pricing method is applied and time-serious regression models are designed for analysis of pre-during-after construction periods. The following sections provide the criteria and description of selected study areas, the source and treatment of data, and the definition and measurement of variables. Finally, model results are presented and explained, based on which conclusions are drawn and recommendations are provided in the last chapter.

CHAPETER 2 LITERATURE REVIEW

2.1 Price Effects of TOD Characteristics and Other Factors

2.1.1 TOD Characteristics

Economic theory suggests that people are willing to pay a premium for access to amenities and these amenities are capitalized into property values (Mathur and Ferrell, 2012). A number of previous literature, studying on the impacts of transit-oriented development (TOD), decompose TOD impacts into separate components, which are segregated into two categories of TOD-generated amenities and TOD-generated dis-amenities. Price effects of TOD-generated amenities contain three major components: transit accessibility effects, pedestrian-friendly network effects, and mixed-use effects. TOD-generated dis-amenities such as traffic congestion, noise and air pollution, would likely reduce property values.

Transit accessibility is one major amenity of TOD. An extensive body of literature explores the price effects of transit proximity.

Economic influence of accessibility starts with the work of Johann von Thunen, who in 1863 theorized about the value of farmland as a function of the land's relative proximity and, thus, its accessibility to the market place. Later research translated his work beyond the farmland context to other types of land use categories, showing similar relationships (Bartholomew and Ewing, 2011).

Theoretically, as transit service increases land accessibility level, the transportation and convenience costs of getting to and from the land becomes lower, leading to increased demand for the land, which raises land values (Landis and Huang, 1995). However, some studies question the applicability of the theory under the consideration that US regions have already established a well-connected, auto-based transport network accompanied by a spatial dispersion of both housing and commercial activities, which limits the effectiveness of non-auto modes (Pucher and Renne, 2003).

Previous research estimating on transit capitalization reveal inconsistent results. Debrezion, Pels, and Rietveld (2007) conducted a meta-analysis method to generalize conclusion among 57 studies. They suggested that transit price effects with residential property values increasing 2.4% for every 250 m closer to a station. While the majority find that transit have a positive impact on nearby property values, some studies show that the impact is relatively modest or even negative in some cases. Strand and Vagnes (2001) confirmed a negative influence of railroad proximity on housing values due to environmental concerns in the case of Oslo. Hess and Almeida (2006) indicated that transit accessibility does not play a large role in property values in Buffalo. The existence of light rail influences land values only modestly and negatively near three stations. Study of Andersson, Shyr, and Fu (2008) shows that high-speed rail way line has small or negligible effects on residential property prices in Tainan region. Mathur and Ferrell (2009) examined single-family home prices near four suburban San Francisco TODs and found no effects from three of them. The negative price effects were explained quite differently, according to each study's specific conditions.

Price effects of transit proximity vary with the differences in transit mode, property type, and measurement methods. According to Hess and Almeida (2006), property near commuter rail stations has higher premiums than light rail or heavy rail, and property near heavy rail accrues greater benefits than property near light rail. Effects are greater with proximity measured by straight line distance, while results are more statistically significant with proximity measured by actual walking distance**.** Comparison among property types indicates that transit premium for multifamily housing is much higher than that for single-family housing (Duncan, 2009). Difference in variable measurements leads to different results as well. Proximity to transport nodes was associated significantly and positively with single-family values, while proximity to transport links was negative but not significant (Seo, Golub, and Kuby, 2014).

Mixed-use development provides commercial, institutional, recreational and other opportunities and services to nearby residents. As an aggregation of mixed-use, TOD promotes convenience for daily activities and opportunities for employment, which can be capitalized as housing price premiums.

Price effects of mixed-use depend on a lot of factors, such as property type, land use scale, mixed-use degree, and proximity to residents. The study of Mathur (2008) indicated that the accessibility to retail jobs increasing "low quality" housing prices while decreasing "high-quality" housing prices. Duncan (2009) measured density of population serving employment in entertainment, food, retail sales and service occupations, representing the amount of non-work activities within a walkable distance of a parcel. He found that this measure of commercial activity has a strong and positive impact within 0.1km from transit stations. Lutzenhiser and Netusil (2001) suggested that housing prices increase with the size of the natural area nearby. They estimated the optimal size of parks and natural areas to be similar to that of a golf course. In addition, previous studies demonstrated that the value of all kinds of open space may be higher in urban areas than in suburban locations. As density increases in urban areas, parks, green ways, and other natural assets provide increased economic benefits (Acharya and Bennett 2001; Anderson and West 2006).

Pedestrian-friendly street design leads to property premiums. It is intuitive that houses located on quieter-calmer-streets sell at higher prices than those located on busy, noise, high-trafficked streets (Hughes and Simans, 1992). Study of Song and Knaap (2003) indicated that people are willing to pay a premium for houses in neighborhood containing interconnected streets and smaller blocks in Portland, Oregon. One example of Boston's "Big Dig" project, the replacement of the elevated Central Artery freeway with an underground facility and the transformation of the surface to a linear parkway and boulevard, illustrated the premiums based on economic analysis of Tajima, which suggested that the demolition of the highway should result in $632 million increase in property values (Bartholomew and Ewing, 2011). Indicators are developed to estimate the pedestrian-friendly network level, such as density of street intersections, steepness of terrain, and area dedicated to park and ride lots Duncan (2009).

While many of the previous studies examine price effects of transit proximity, mixed-use, and street design independently, some studies move forward and explore the synergistic effects among the three major TOD characteristics and other related factors.

Study of Matthews and Turnbull (2007) indicates that price effects of mixed-use are associated with neighborhood street patterns. Retail uses within walking distance has no significant effect in automobile-oriented neighborhoods with curvilinear and cul-de-sac street patterns; while in pedestrian-oriented neighborhoods with interconnected streets, retail proximity significantly influences property values. Atkinson-Palombo (2010) suggested that the impacts of TOD zoning are associated with neighborhood mixed-use levels. In single-use residential neighborhoods, the adoption of TOD zoning has a negative effect on real estate price, whereas TOD zoning is accompanied by a 37 percent premium for condos located in mixed-use areas. The interaction relationship between transit proximity and pedestrian environment is illustrated in the study of Duncan (2009). It shows that under the condition of good pedestrian environment, a condo near a transit station has a significantly higher value than one not near a station. Oppositely, a condo in a less walkable residential neighborhood near a park-and-ride station can have lower values than one in a similar neighborhood not near a station.

In addition to street design, transit proximity effect is also conditioned by specific neighborhood attributes and station area characteristics. Bowes and Ihlanfeldt (2001) made use of interaction variables to test the relationship between transit proximity and neighborhood income. The results show that the premium paid for being close to a station is greater in high than in low income neighborhoods. An example of Rosslyn-Ballston corridor of Arlington County suggests that the capitalization of transit proximity benefits is not merely a function of a property's proximity to a station, but also the station's proximity to the center of the region. As the station distance from CBD increases, the accessibility-related property value impact tapers off (Bartholomew and Ewing, 2011). Similarly, Kay, Noland, and Dipetrillo (2014) found that access to stations with direct New York City service is valued slightly higher than access to regular study stations. Chen and Haynes (2015) demonstrated that high speed rail has a considerable impact on housing values in medium and small cities but a negligible impact in larger capital cities, resulted from the competitive nature of housing market in Chinese capital cities.

2.1.2 Other Factors

In addition to TOD related characteristics mentioned above, property value relies on a lot of other factors, including three main categories of structural characteristics, locational conditions, and social-economic attributes.

Structural characteristics typically include the square footage of living space, the number of bedrooms and bathrooms, the age of house, floor area ratio, number of fireplace, and other features known to affect sales transactions. Since they reflect property intrinsic attributes, the influences on property values are mostly significant. Locational conditions are considered important factors affecting property values. Major features surrounding study areas are identified, such as major street, freeway interchange, parks and open space, commercial land uses, city center or area sub-centers. While proximity of these features are often measured by straight line distance, some studies use dummy variables to reflect their influences, such as whether the property is within a certain mile of freeway and whether it is on the east side of light rail line. Social-economic attributes typically contain population density, household income, and racial composition. Some attributes identified by previous studies vary with specific considerations, such as violent crime rate, occupancy rate change, and population growth rate. Educational level is indicated by average SAT math score, and college-educated proportion in some cases.

However, there are only a small number of studies involving variables reflecting nuisances such as traffic congestion, noise and air pollution. While previous studies attempt to involve appropriate related variables, the identification and measure of such variables are difficult. Because there are so many factors affecting property values and so many measurement methods, involving appropriate variables or conducting accurate measures with the limitation of data sources are quite impractical for most researches.

Detailed information of methods, variables, and results are summarized in Table 2-1.

Table 2-1. Summary of Major Studies

Authors	City	Property Type	Transit Mode	Study Area	Method	Major Variables	Main Result
Landis, Guhathakurta, and Zhang, 1995	San Jose and Sacramento ,CA	single-family houses	BART, CalTrain, and three light rail systems in San Jose and Sacramento	4180 avaiable single-family transactions from TRW-REDI data	hedonic price models	floor area; lot size; # bedrooms; # bathrooms; householed income; % White, Asian, Black, White; % home owners;network distance to transit station; distance to freeway interchanges;within 300m of transit line; within 300m of freeway	The capitalizaiton effects of rail transit can be significant. The extent to which transit service is capitalized into increases in home prices depends on the quality of service. BART and San Diego Trolley are more likely to generate significant captitalization effects.
Bowes and Ihlanfeldt, 2001	Atlanta,GA	single-family house	Metropolitan Atlanta Rapid Transit Authority(MARTA) rail stations	Atlanta region	hedonic price model in the semi-log from and auxiliary models for neighborhood crime and retail activity	lot area;house age; # fireplaces; house has basement; tract proximity to employment; # road miles to CBD center; within one-half mile road distance highway interchange; within one mile to two miles road distance of highway interchange; density of manufacturing employment; density of retial employment; % housing units occupied by renters; % black; median income;% tract within one-half mile of a freight rail line; density of total crimes; dummy variables of distance to MARTA rail stop	Properties within a quarter of a mile from a rail staion are found to sell for 19% less than properties beyong three miels. Properties that are between one and three miles have a significantly higher value compared to those farther away. Premium paid for being close to a station is greater in high-income than in low-income neighborhoods.
Cervero and Duncan, 2002	Santa Clara County, CA	office, commercial, light industrial properties	light rail and commuter rail	0.25 mile buffer of stations	hedonic price models	distance to CBD; floor area; lot size; house age; shop use; street frontage; road width; commercial zone; % college-educated	Distance to HSR station is only significant at one-tailed in seven of eight models. Even is tentatively accept the price-distance effect, the amount is no more than a 3% -4% price premium.
Hess and Almeida, 2006	Buffalo,NY	residential property	light rail	0.5 mile buffer of 14 light rail stations	hedonic price models	straight line distance to rail staion;walking distance along street network to rail station; parcel area, structure age, # bedrooms; # bethrooms; single-famiyl housing; # fireplaces; presence of basement; distance to CBD, the nearest parek, Delaware Park; East side dummy variable; property crime rate; violent crime rate; median income; occupancy rate change; population growth rate	Every foot closer to a light rail staitonincreases average property values by $2.31(using geographical straight-line distance)and $0.99(using network distance); Proimity effects are positice in high-income station areas and negative in low-income station areas;
Andersson, Shyr and Fu, 2008	Taiwan	residential property	high-speed rail	Tainan metropolitan area	Hedonic regressional models in log-linear, semi-logarithmic and linear Box-Cox functional forms	floor area; lot size; structural age; # stories; shop/dwelling use; street frontage; road width; commercial zone; residential zone; mean household income; college-educated; distance to CBD, HSR station, freeway interchange	The small or negligible effect of high-speed railway (HSR)accessiblity on residential property prices in the Tainan region is a reflection of expensive fares in combination with the inaccessible location of the HSR station.
Duncan 2009	San Diego, CA	condominium units	Trolly system	1 mile network buffer	hedonic pricing models with interaction terms	floor space;structure age;# bathrooms;# bedrooms;# garage space; view; **# street intersection;** people-serving jobs; % slope; parking area; parcels within 50 metres of a grade-separated highway; network distance to the nearest station; series of dummy variables representing station catchment areas	Station proximity has a significant stronger impact when coupled with a pedestrian-priented environemnts.TOD has a synergistic value greater than the sum of its parts.

Mathur and Ferrell,2012	San Jose, CA	single-family house	light rail system with sub-urban TOD	0.5 mile radius buffer	hedonic pricing method: fixed effect ordinary least squares regression models	building area;lot size;house age; # bathrooms; # bedrooms;distance to TOD;distance to light rail line;within 1/8 mile of TOD;within 1/8 mile of light rail line;distance to the nearest multi-family development,bus stop, major street, freeway; % change of median household income; % change in population; % white populaiton	TOD's price effect dissipates after 1/8 mile. Housing price within 1/8 mile were 18.5% higher than the prices more than 1/8 mile from the TOD in post-TOD period; 7.3% higher during the construciton period; not statistically different in pre-TOD period.
Yan, Delmelle, and Duncan, 2012	Charlotte, NC	single-famiyl house	light rail	1 mile buffer of light rail	hedonic Price Analysis with time-series models	structure age; height; no fuel;central air conditioning; # fireplaces; building grade; network distance to nearest transit station	Proximity to the future rail corridor had a negative influence on home prices before the rail system began operation; housing prices reacted positively to light rail investment during the operational phase;
Ma,Ye,and Titheridge, 2013	Beijing	apartment units	11 rail lines and 1 BRT line	built-up rea within the 6th Ring Road in Beijing	hedonic regression model in semi-log form	distance to rail station, city center,nearest subcenters;ratio of commercial and entertainment land uses;whether has elementary school; administration fee	An average price premium of around 5% for properties near rail transit stations, but no statistically significant effects were detected at BRT station areas. Increase in distance to city center or increase proximity to low- and medium-income neighborhoods will decrease the relative value of station proximity.
Seo, Golub, and Kuby, 2014	Phoenix, AZ	single-family house	light rail	the city of Phoenix	hedonic model using generalized spatial two-stage least-squares estimaiton	living area; lot size; # bathroom fixtures; house age; presence of pool; nearest green park, desert park, golf course; nearest distance from city center; dummy varibles of distance from highway exit, highway, light rail station, light rail track;median household income; populaiton density; % covered by trees; % covered by grass; highway lies above ground level; highway lies below ground level	Proximity to transport nodes was associated significantly and positively with single-family detached home values.Proximity to transport links was negative but not significant.
Kay, Noland, and Dipetrillo, 2014	New Jersey	residential property	New Hersey Transit (NJT) rail system with TOD	2 mile radius buffer of eight sampled NJT stations	Hedonic regression in the log-transformed form	distance to nearest study station, nearest NYC station; income, # rooms, populaiton density,effective tax rate, % Black or African American,% of HU large multifamily, % of HU single family attached, park accessibility score, violent crime rate,average SAT math score	Access to stations with direct New York City service is valued slightly higher than access to study stations.
Chen and Haynes, 2015	22 cities along BJHSR line	housing unites in communities	Beijing-Shanghai high speed rail (BJHSR)	50 km buffer along the BJHSR line	hedonic pricing methods in the forms of OSL Box-Cox, and a spatial econometric model	housing value; area size; completed or not; floor area ratio; greening ratio; per capital income; populaiton density; whether it is a residential building, apartment, villa, office building; distance to HSR station, city center, main road;whether bus stop, school, park, hospital is nearby; whether locates in provincial capital.	BJHSR service has a considerable regional impact on housing values in medium and small cities but a negligible impact in larger capital cities.

2.2 Analysis Methods

The term "hedonic modeling" was coined by Court (1939) and popularized by researchers such as Griliches (1961) and Rosen (1974), whose hedonic price model explained the composition of housing price by disentangling the bundle of housing services. The concept of housing as a commonly traded with a specific set of characteristics are widely accepted (Morancho, 2003) and Hedonic Pricing Analysis (HPA) has been employed to lots of studies investigating on property values.

Empirical studies typically use sales data of real estate transactions across a wide range of development conditions to tease out the amount that buyers are willing to pay for the individual features that make up the total price of a piece of real estate (Dubin, 1998). Marginal price of each individual feature is estimated in hedonic regression models.

Different functional forms of hedonic regression models are employed in previous studies. A linear function implies constant marginal implicit prices, which is only tenable under the situation that constant returns to sale in production or costless repackaging of two or more bundles (Goodman, 1998). In non-linear function forms, the price of an additional unit of an attribute depends on the quantity already supplied and in the most common specifications also on the quantity of other attributes (Andersson, Shyr and Fu, 2008). It is examined that some structural and neighborhood factors have non-linear relations with housing price, such as interior square footage. Many other studies shows that non-linear functions are more suitable when applied to typical housing markets. Seo, Golub, and Kuby (2014) tested linear, semi-logarithmic, and trans-logarithmic functional forms in their study of Phoenix light rail system. Chen and Haynes (2015) made use of a robust ordinary least square regression, a Box-Cox transformed maximum likelihood form, and a spatial econometric modeling form to demonstrate robustness of estimations. Model results might vary with different regression forms. “The log-linear function explains more of the variance and has greater log likelihood. All the Box-Cox functions have slightly greater log likelihood than the log-linear function with the exception of the simple left-hand side model” (Andersson, Shyr and Fu, 2008).

Many studies conducted time-series models to analysis the impacts of different construction periods. Ferguson (1988) examined the relationship between urban transit and single family housing prices in Vancouver and his work shows that the urban transit has an impact on housing market before the system operations began. Mathur and Ferrell (2012) estimated models in pre-TOD construction period, TOD construction period, and post-TOD construction period. They found TOD’s price effects are significantly positive in the construction and post-construction periods. Similarly, Pan (2013) made an analysis of light-rail in Houston and indicated that there is a significant increase in property values following the announcement that the light-rail line would be constructed**.** However, Yan, Delmelle, and Duncan (2012) identified four time periods of pre-planning, planning, construction, and operation phase of light rail system. Their results suggest that proximity to the future rail corridor has a negative influence on housing price in the first three periods.

Geographical extent of the market is one major issue concerned by hedonic price functions. Empirical studies demonstrate that if the assumed market is larger than its real size, it leads to biased parameter coefficients; if the assumed size is smaller, it leads to parameter estimates with lower precision (Palmquist, 1991). In the case of impacts from TOD or rail services, many studies indicates that the impact is within a certain proximity, roughly from a quarter mile to two miles. According to Goodman and Thibodeau (1998), limiting the study area's spatial extent has the benefit of making it more homogeneous, which simplifies the model specification and is likely to lead to a more accurate model. Most previous researches focus on buffer areas around transit stations using a radial distance up to one mile around stations (Hess and Almeida, 2006).

According to Bartholomew and Ewing (2011), HPA is classified as one of several revealed-preference (RP) approaches for determining public goods value, which makes use of empirical data to determine people's willingness to pay. HPA has the intuitive strength of being able to demonstrate what people actually choose when they are required to prioritize competing demands for time and money. On the contrary, it shares the same limitations with RP approaches. One fundamental one is its inability to test demands for goods that do not yet exist, because the analysis is based on observed available data. Another common issue with hedonic real estate models is spatial dependence, which implies spatial correlation among observations in cross-sectional data that are assumed to be independent (Anselin 1988; Kim et al., 2003). To obtain unbiased, consistent, and efficient estimates, spatial dependences should be tested and addressed with proper methods if either one or both spatial effects exist

CHAPTER 3 METHODOLOGY

This study seeks to estimate the capitalization of light rail transit-oriented development (TOD) on residential properties. While a number of previous studies investigate TOD impacts by its component characteristics, the study aims to capture its integrated influence.

3.1 Question and Hypothesis

Research question can be stated as: How do light rail TOD impact residential property values? In order to answer this question, two dimensions are given emphasis to explore, including: the different impact caused by the difference in residential properties; the different impact caused by different time periods. Generally speaking, I suppose as TOD accessibility increases, residential property values increases; impact of TOD are different across pre-construction, during-construction, and after-construction periods. Comparisons among different residential properties and across time periods can be conducted.

3.2 Conceptual Model

Normally, TOD is centered at a light rail station. TOD impacts cover both the areas within its boundaries that apply specific policies and designations, and the areas adjacent to it. To analyze the integrated effects of TOD component characteristics, the study considers TOD applied areas as a whole and differentiate it from TOD impact areas. Therefore, residential properties within TOD boundaries are not considered. See Figure 3-1 of Targeted TOD Impact Area.

Under the consideration of data availability, residential property values are represented by single-family house values in the study. TOD proximity is measured as distance to the light rail station which it is centered at to reflect the degree of TOD integrated impacts on residential properties. Relevant structural characteristics, locational conditions, and social-economic attributes that affect property values are identified based on study and are controlled in regression models. In addition, policies and decisions made by local governments and real estate agencies may have significant or potential influences on property values. Residential preference may affect property value by affecting market demand through different time periods. The overall economic environment has great impacts on residential properties as well. See Figure 3-2 of Conceptual Model of Identified Factors.

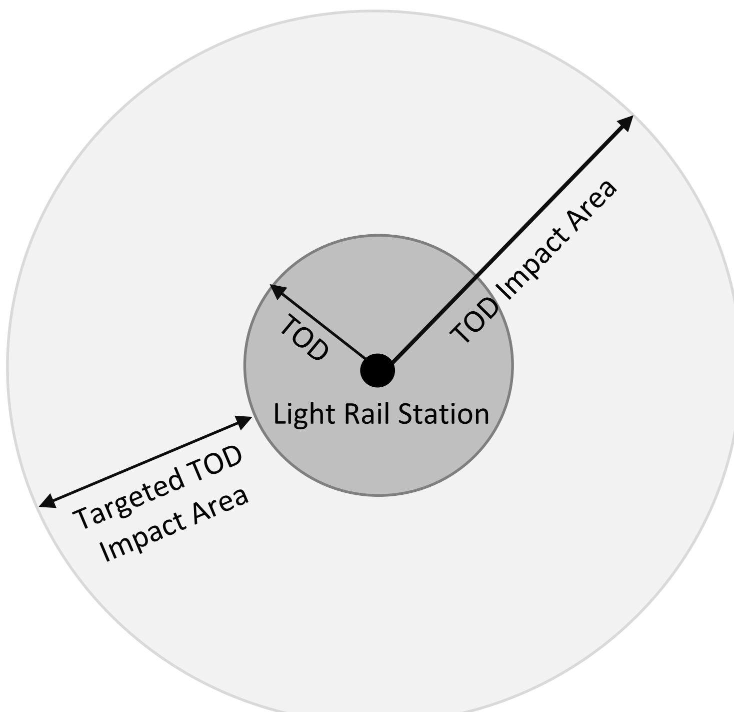

Figure 3-1. Targeted TOD Impact Area

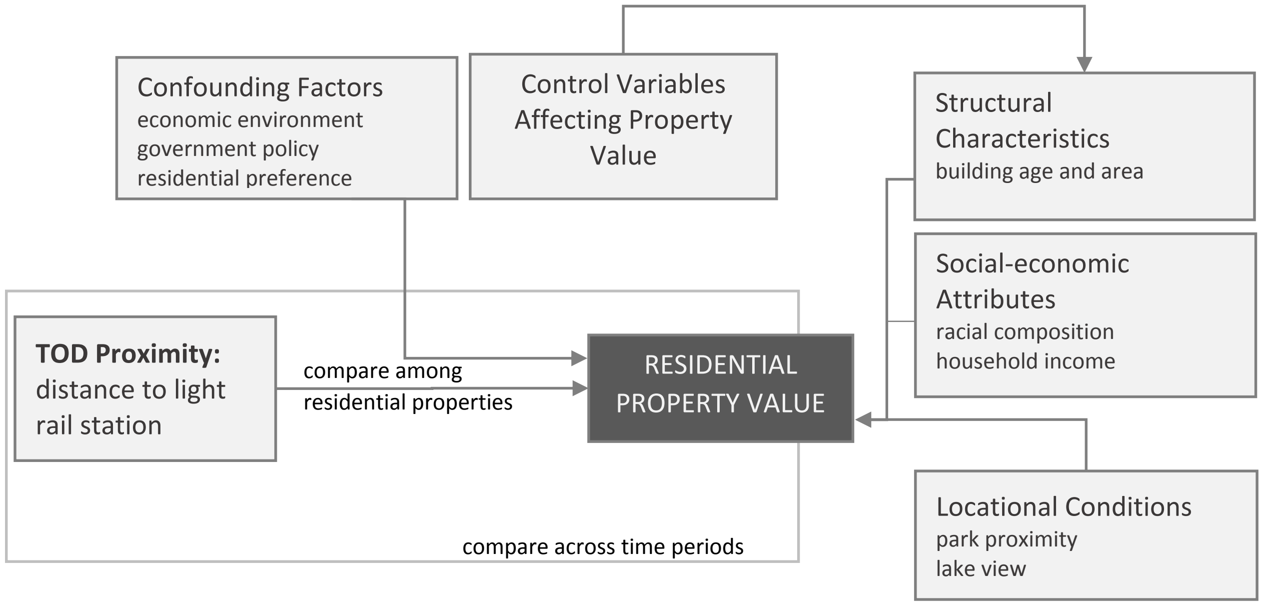

Figure 3-2. Conceptual Model of Identified Factors

3.3 Statistical Analysis

3.3.1 Hedonic Pricing Analysis

Hedonic pricing analysis for assessing real estate price is based on the understanding that the value of an individual piece of real property is neither monolithic nor completely intrinsic to the property itself, but is the result of a multitude of characteristics, many of which come from the context in which the property is situated (Kestens, Theriault, and Rosiers, 2004). It has been broadly used in many previous studies, for decomposing property components and estimating the contributory values of each characteristic.

In this work, residential property values are subject to impacts of many constituent parts, including TOD proximity and characteristics, structural characteristics, locational conditions, social-economic attributes, and other confounding factors. Hedonic pricing method is well suited to separate impacts from all related factors and examine the relations between each of them with residential property values. The study applies hedonic regression models in linear form:

$$P = c_0 + \sum \alpha_i T_i + \sum \beta_i L_i + \sum \mu_i S_i + \sum \upsilon_i E_i + \varepsilon$$

Where c_0 is a constant, P is the adjusted transaction price of single family property, T_i are the TOD proximity variable; L_i are the other identified locational variables; S_i are structural variables; E_i are related social-economic variables, ε is the regression residual.

3.3.2 Regression Models

To analyze TOD impacts of different time periods, pre-during-after models are conducted in the basic form of hedonic regression function. Residential properties' transaction year are identified and classified into three categories: before TOD construction, during TOD construction, and after TOD construction. Comparisons among different properties and across different time periods are then conducted.

Chapter 4 Study Area

4.1 Link Light Rail

Link Light Rail is a rapid transit rail system in the Seattle metropolitan area of Washington State. It was first proposed and approved in 1996, in response to population growth and urban development. The original designation involves two rail lines, Tacoma Link and Central Link, which were shortened afterwards due to financial and political difficulties. In 2003, Tacoma Link light rail line opened, consisting of six stops and 1.6 miles through downtown Tacoma. Then the construction of Central Link light rail line began. By the late 2009, the construction was completed and opened to the public, running between Westlake station and Seattle-Tacoma international Airport. In 2016, Central Link was further extended by adding two more stations, Capitol Hill station and University of Washington station. Sound Transit is the region's mass transportation agency that take charge of the designation, construction, and operation of Link Light Rail. It has made further plans to extend Link Light Rail to Lynnwood Transit Center to the north, and Downtown Bellevue and Overlake Transit Center to the east.

Currently, the Central Link light rail travels 18.8 miles between UW station and Seattle-Tacoma international Airport. It consists of 13 stops along the way and runs at 6, 10 or 15 minutes intervals depending on the time of day.

4.2 Station Area Overlay District

Before the construction of Central Link light rail, the City of Seattle started a program of Station Area Planning in 1998. In partnership with Sound Transit, Station Area Planning engaged city departments, community representatives, and partner agencies in planning and development work for a quarter mile around proposed light rail stations. The program refined the community's vision, identified public and private investments, and made specific policy choices and designations to guide future development of the station areas. In 2000, the Seattle City Council adopted 10 Station Area Concept-Level Recommendation packages. In 2001, the Council further passed the Station Area Overlay legislation.

Station Area Overlay legislation establishes Station Area Overlay Districts (SAOD) and rezones around eight future light rail stations. The primary goal of the legislation is to promote Transit-Oriented Development (TOD) and forward neighborhood goals for walkable town centers. Specific policies are applied to SAODs: supporting existing business by allowing for a one-time expansion of certain existing business; providing off-site residential parking by leasing parking on nearby site; prohibiting specific uses such as vehicle repair and warehouse; promoting flexibility in commercial zones by allowing Single-Purpose Residential (SPR) use; encouraging more housing development by removing 64% upper level coverage limits, in which case residential buildings in commercial zones of SAODs can use the entire lot area on all levels for residential units. Zoning changes are made primarily within SAOD boundaries. For most cases, zoning changes provide greater design flexibility by removing height and density limits for residential uses, promoting more retail and commercial uses in residential and commercial zones, and reinforce pedestrian activities by adding pedestrian overlay designation along the main corridors. The above policies and designations synergistically facilitate TOD by promoting high-density and mixed-use development, and prevent auto-oriented development in SAOD.

4.3 Study Area Selection and Description

In order to analysis the impact of light rail TOD on residential property values, the study areas should satisfy the following criteria: TOD should be around light rail stations; land-value benefits from TOD take time to accrue, so the operation of light rail stations should be long enough, in this study, more than five years; the study area should contain a certain number of single-family houses, before and after TOD implementation; the study area should not overlap with TOD, in order to analysis the integrated impact of TOD.

Therefore, Station Area Overlay Districts, which are established around light rail stations and promote TOD, are reviewed for study area selection. Considering of the distance between each two light rail stations, buffers are created within 1.0 mile radius of station. Suitable study areas should be the land between the boundaries of SAOD and station buffer. See Figure 4-1 of Link Light Rail Station and Buffer.

The eight approved SAOD includes neighborhoods of Henderson, Othello, Columbia City, McClellan, Beacon Hill, First Hill, Capitol Hill, and University District. Since the Capitol Hill station and University District station opened in 2016, less than 5 years, these two SAODs are not suitable for the study. Land within the station buffer of First Hill neighborhood are mainly for commercial and multi-family uses, so it does not have enough single-family data for the analysis. The station buffers of McClellan and Beacon Hill are overlapped with too many buffers of other stations, making it difficult to differentiate the impacts of each TOD separately to the single-family houses within the overlapped area. Therefore, these two are excluded from the study. The left three SAODs in the neighborhoods of Henderson, Othello, and Columbia City are the ones satisfy all the criteria.

Therefore, suitable study areas are the areas between the boundaries of 1.0 mile radius from Rainer Beach, Othello, and Columbia City stations and SAODs of Henderson, Othello, and Columbia City neighborhoods. To be simplified, study areas are referred as Rainer Beach site, Othello site, and Columbia City site. The borders of the three SAODs are represented for the TOD borders of Rainer Beach site, Othello site, and Columbia City site, and they are referred as Rainer Beach TOD, Othello TOD, and Columbia City TOD in the study. See Figure 4-2 of Selected Sites.

After the Station Area Overlay legislation was approved, a number of actions were implemented to promote Transit-Oriented Development. The Seattle Housing Authority (SHA) built approximately 1400 mixed-income rental and ownership units adjacent to the Othello Station. The construction is completed in 2005. For other two study sites, the new constructions and adjustments took place gradually from 2001. All TOD components in the three sites completed before the light rail stations went in service in 2009. Therefore, the TOD timeline is divided into three periods: 1996–2001period before the construction of TOD and station; 2002–2009 period during the constructions; 2010–2016 after TOD construction completed and stations went into service.

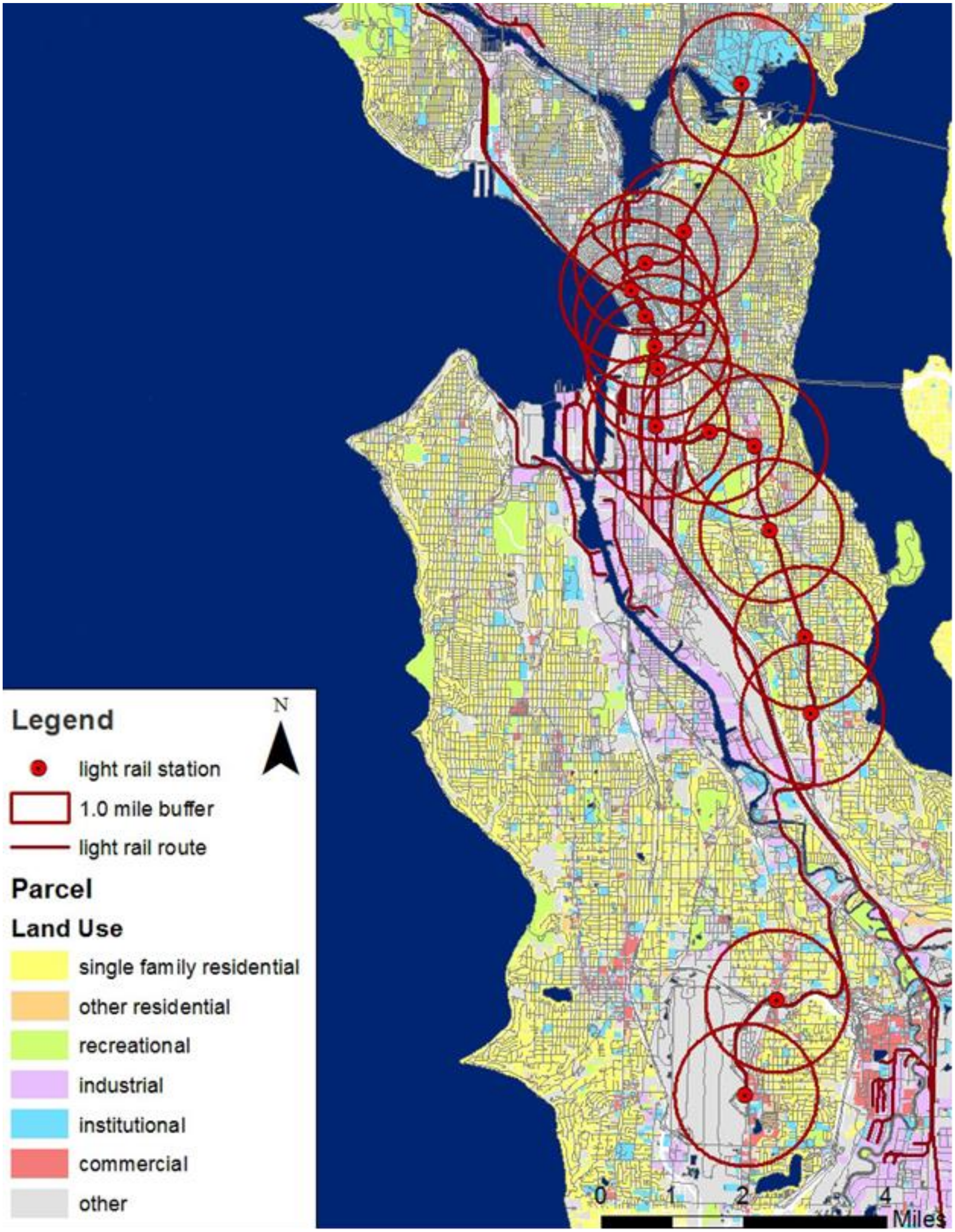

Figure 4-1: Link Light Rail Station and Buffer

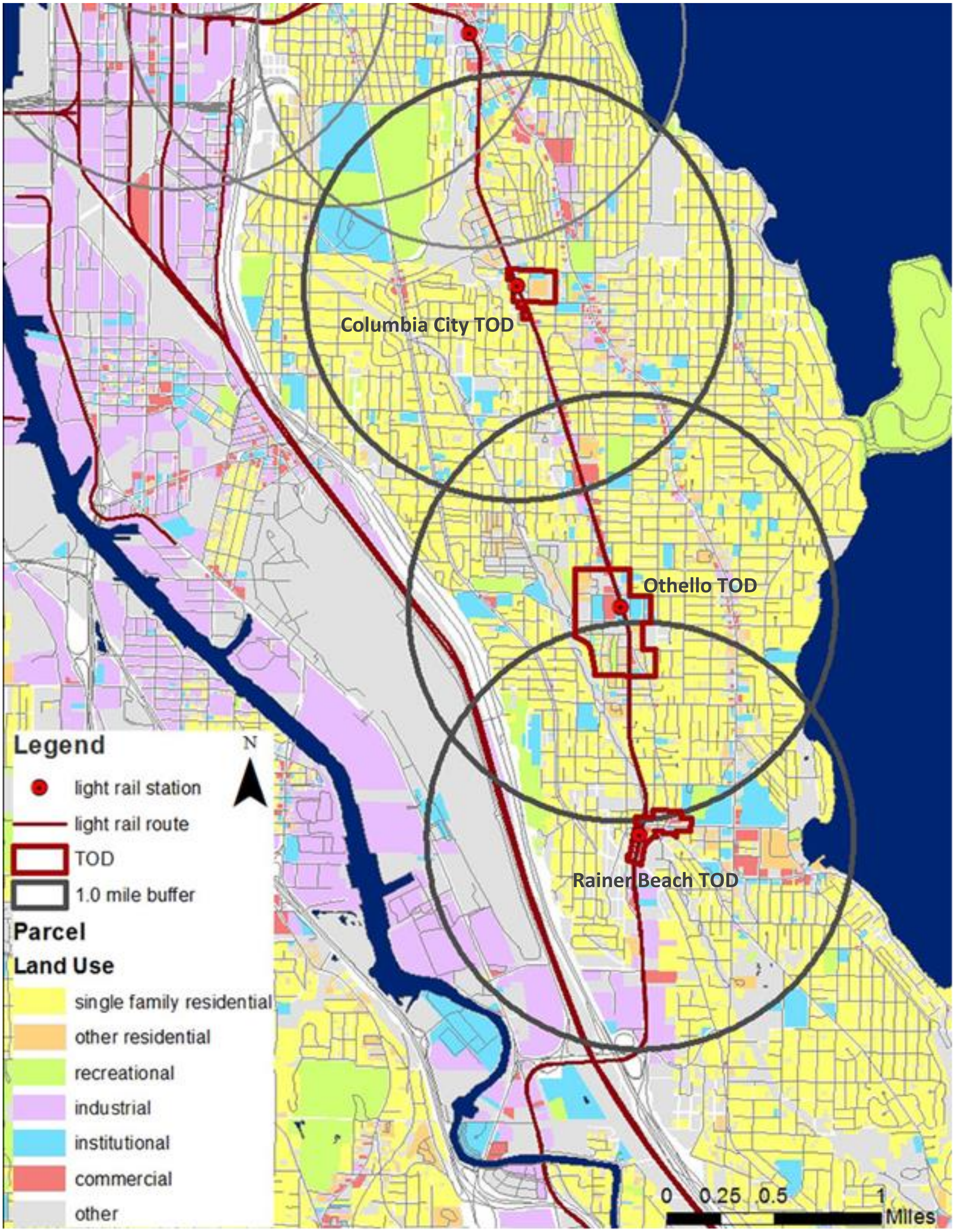

Figure 4-2: Selected Sites

Chapter 5 Data

5.1 Data Source

King County GIS Center contains geospatial databases of administrative, environmental, transportation, recreation and property information. Three study sites and the major features in the area are established making use of these databases. Parcel data included in the property database provides locational and identification information of single family houses. Present use of each parcel is also included, which is used to identify different kinds of land uses.

King County Assessor provides parcel, residential building, and real property sales database. Some physical and structural characteristics of single family houses are extracted from parcel and residential building database. Transaction data and sale price information are stored in the real property sales database. Attributes of “major” and “minor” are used to generate “pin code” to link with geospatial parcels.

United States Census offers American Community Survey (ACS) data providing facts of people, housing, and business at the block-group level. Block-group shape-file is available for identifying parcels of different block groups. Attribute of “GEOID” is used to link the information to geospatial parcels.

City of Seattle Legislative Information Service provides detailed information of council bills and ordinances. The ordinances relating to designate boundaries for the Station Area Overlay District are recorded on the website. Maps of Station Area Overlay District Boundaries for Link light rail stations are available to acquire.

S&P/Case-Shiller Home Price Index Series measures changes in the total value of all existing single-family housing stock. It provides home price index of Seattle, measuring the average change in value of residential real estate in Seattle given a constant level of quality from 1990 till now. Index of different years is used for inflating the previous housing prices into present dollars, in order to capture the effect of economic change (especially the Subprime Crisis in U.S. during 2007-2009) on real estate market.

5.2 Parcel Extraction

Three study areas between TOD boundary and 1.0 mile buffer around each Link light rail station are established using ArcMap, including Columbia City site, Othello site, and Rainer Beach site. Some areas within the three sites are overlapped with each other. For parcels in those areas, calculate their distance to stations and distribute the parcels to the nearest one: if the parcel is closer to Othello station, it is counted as a parcel of Othello site in the regression models. For this purpose, buffer around Mt. Baker station is used to eliminate parcels in Columbia City buffer that are closer to Mt. Baker station. Therefore, all the parcels are distributed to the three study sites according to their distances to stations.

Qualified parcels are identified through four steps:

1) Parcels should be of single family uses. The attribute of present use from parcel data shows the land use classifications. Values equal to 2, 6, and 9, indicating single family uses in residential use/zone and C/I zone. Parcels with other values are excluded. There are 12217 satisfied parcels in total, out of which 5216 are in Columbia City site, 4351 are in Othello site, and 2650 are in Rainer Beach site. See Figure 5-1of Properties by Study Sites.

2) Parcels should have only one living unit. Residential building table from King County Assessor records the number of living unit for each parcel. Since the study targets on single family properties, parcels with more than one living unit number are eliminated. 671 parcels do not meet the requirement and are removed.
3) Parcels characteristics should keep consistent as they were sold. Transaction date is recorded in the attribute of document year from real property sales table, and renovation year is recorded in residential building table. Link these two tables and compare the value of them. Since only current conditions of parcels are reflected, single family houses whose transaction date smaller than renovation date are excluded.
4) Parcels attributes' values should all be available and reasonable. Database from other resources are linked with geospatial parcel shape file in ArcMap. Some of the parcels that could not be matched with recorded data are eliminated. Some of the parcels whose added attributes values are obviously unreasonable are removed.

In summary, there are 3443 qualified parcel records, out of which 1436 belongs to Columbia City site, 1207 belongs to Othello site, and 800 belongs to Rainer Beach site. If classified by time periods, there are 519 records for pre-construction period, 2486 for during-construction period, and 438 for after-construction period. See table 5-1 of Qualified Parcel Records.

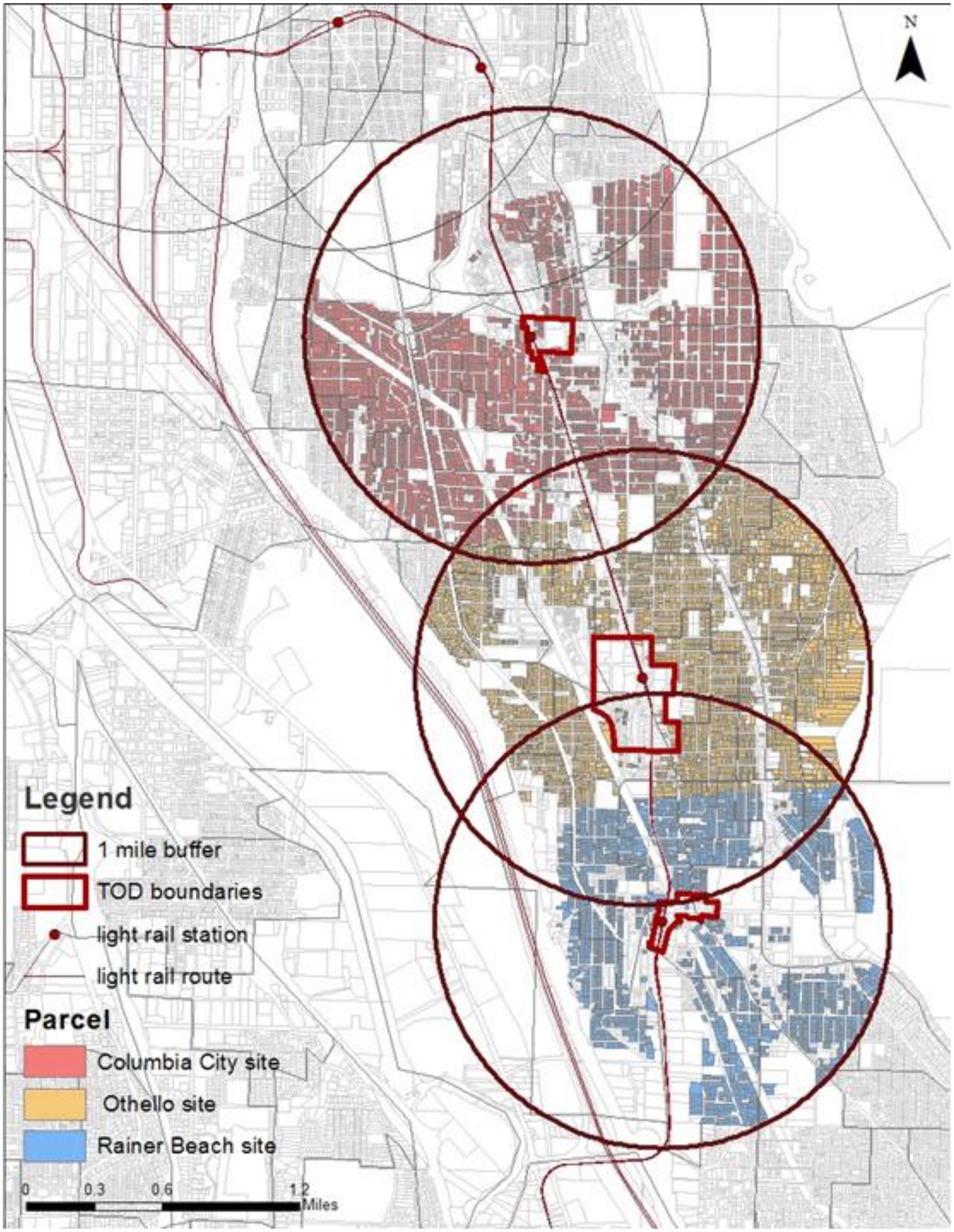

Figure 5-1. Properties by Study Sites

Table 5-1: Qualified Parcel Records

Station \ Period	pre-construction period (1996-2001)	during-construction period (2002-2009)	after-construction period (2010-2016)	Total
Rainer Beach station	112	569	119	800
Othello station	170	876	161	1207
Columbia City station	237	1041	158	1436
Total	519	2486	438	3443

5.3 Variables

5.3.1 Explanatory TOD Variables

Integrated impact of TOD components is represented by TOD proximity, which is measured by distance from residential properties to the nearest light rail station. Instead of using continuous distance variable, the study sets binary distance bands as 0-0.25 mile, 0.25-0.50 mile, 0.50-0.75 mile, and 0.75-1 mile to light rail station and applies these dummy variables in regression models. These variables are calculated by using spatial analysis tool in ArcMap.

5.3.2 Control Variables

Social-economic attributes of single family houses are extracted from related survey results in U.S. Census and calculated in ArcMap. Since the information is generated in block-group level "GEOID" attribute and block-group data are used to attach the information to each parcel. ArcGIS tools of spatial join, calculate geometry are used to calculate percentage of white, as an indicator of race composition. Other social-economic factors include median household income. Social-economic attributes are generated in block group level.

Locational conditions of single family houses are extracted from parcel table in King County Assessor and measured using spatial analysis tool in ArcMap. Lake Washington view is measured by dummy variables, with value "0" indicating no lake view and value "1" indicating some level of lake view. Traffic noise is measured in this way too. These two factors are linked with single family houses by "pin code" attribute in ArcMap.

Major features in the study area are generated in ArcMap, including transport network, recreational facilities, and natural resources. Distance from each parcel to the nearest park, nearest commercial land use, freeway, and lake Washington are calculated. Network analysis is used for generate intersections from transport networks, in order to calculate number of intersections in block group level.

Structural characteristics are extracted from residential building table and parcel table of King County Assessor, including building grade, condition, bedrooms number, total finished area above grade, total basement area, and lot size. Attributes of document year from sale price table and built year from residential building table are used to calculate building age.

5.3.3 Dependent Variable

Transaction prices of single family houses are recorded in real property sales table from King County Assessor. S&P/Case-Shiller Home Price Index data for Seattle from 1996 to 2016 is extracted to inflating previous price to present dollars of 2016.

The computational formula is:

$$V_n = V_p \times (H_n / H_p)$$

Where V_n is the value of dollar in present year; V_p is the dollar value in past year; H_n is the Home Price Index in present year; H_p is the Home Price Index in past year.

The adjusted transaction price is applied to regression models as the dependent variable.

5.3.4 Variable Definitions and Sources

All of the above variables are applied to regression models. See Table 5-2 of Variable Definitions and Data Sources.

Table 5-2 Variable Definitions and Data Sources

VARIABLE	*DEFINITION*	*MAJOR SOURCES*
DEPENDENT VARIABLE		
VN	single family house transaction price adjusted to 2016 constant dollars	King County Assessor real property sales data S&P/Case-Shiller Home Price Index Series
EXPLANATORY TOD VARIABLES		
D_DUMMY1	1, if property is located within 0.25 mile distance from light rail station, 0 otherwise	King County GIS shape file, City of Seattle Legislative Information Service
D_DUMMY2	1, if property is located within 0.25-0.5 mile distance from light rail station, 0 otherwise	King County GIS shape file, City of Seattle Legislative Information Service
D_DUMMY3	1, if property is located within 0.5-0.75 mile distance from light rail station, 0 otherwise	King County GIS shape file, City of Seattle Legislative Information Service
LOCATIONAL VARIABLE		
D_PARK	distance to nearest park	King County recreation shape file
D_COMUSE	distance to nearest commercial land uses	King County administrative and parcel shape file

D_LAKE	distance to lake Washington	King County environmental shape file
D_FREEWAY	distance to freeway	King County transportation shape file
INTERSECTIONS	number of intersections in block group level	King County transportation shape file, U.S. Census block group data
TRANOISE	1, if the property has detected traffic noise, 0 otherwise	King County Assessor parcel data
LAKVIEW	1, if the property has other nuisance, 0 otherwise	King County Assessor parcel data
SOCIAL-ECONOMIC VARIABLE		
P_WHITE	percentage of white population summarized to the block level	American Community Survey 5-year (2010-2014) B02001 Data
M_INCOME	median household income in block-group level	American Community Survey 5-year (2010-2014) B19013 Data
STRUCTURAL VARIABLE		
BEDROOMS	number of bedrooms	King County Assessor residential building data
AGE	building age	King County Assessor residential building and real property sales data
LOT SIZE	square footage of lot	King County Assessor parcel data
TOTFINISHED	square footage of total finished area above grade of the building	King County Assessor residential building data
TOTBASEMENT	square footage of total basement of the building	King County Assessor residential building data
CONDITION	the score representing the condition of the building from low to high: 1 poor, 2 fair, 3 average, 4 good, 5 very good; 0 otherwise	King County Assessor residential building data
BUIGRADE	the score representing the building quality from low to high:1 cabin, 2 substandard, 3 poor, 4 low, 5 fair, 6 low average, 7 average, 8 good, 9 better, 10 very good, 11 excellent, 12 luxury, 13 mansion	King County Assessor residential building data

5.4 Descriptive Statistics

The flowing descriptive statistics table summarize the mean and standard deviation of each variable for all three sites models of pre-during-after construction periods.

The average inflated single family house price increases from pre-construction period to after-construction period. The price fluctuation is most obvious during the construction time, indicating the unstable market environment at that time. The mean and standard deviation of distance dummy variables across the three periods are similar.

In terms of locational factors, the mean and standard deviation of most variables do not change much across pre-during-after construction periods. The mean distance to nearest park is around 980 feet for pre and during construction periods, while it decreases slightly after TOD construction completed. The mean distance to commercial land uses decreases as TOD construction completed, while the mean traffic noise level increases in the after-construction period. For social-economic factors, percentage of white increases slightly when TOD construction completed. Median household income increase gradually across the three periods from $58873.57 to $60273.05. As for structural factors, some of their mean values increases in during-construction periods and decreases when the construction was completed, such as lot size and total basement area. The condition and building grade of properties increase across time periods. Square footage of total finished area above grade of the building increases stably from 1218.56 to 1295.99 square feet from pre-construction to after-construction period.

Table 5-3 Descriptive Statistics

VARIABLE	Pre-Construction Period (1996-2001)		During-Construction Period (2002-2009)		After-Construction Period (2010-2016)	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
DEPENDENT VARIABLE						
Vn	320111	197437	375023	264075	388105	176094
EXPLANATORY TOD VARIABLE						
D_Dummy1	0.07	0.258	0.07	0.250	0.05	0.223
D_Dummy2	0.25	0.434	0.26	0.441	0.25	0.434
D_Dummy3	0.37	0.482	0.36	0.480	0.39	0.488
LOCATIONAL VARIABLE						
Intersections	55.95	20.309	56.37	19.793	55.72	19.994
D_Park	981.83	612.53	984.01	630.55	947.84	588.76
D_Freeway	4897.53	2492.09	4907.55	2460.28	5061.69	2488.29
D_Lake	4523.77	2633.64	4467.15	2583.74	4014.31	2594.58
D_ComUse	803.49	486.16	813.93	491.25	777.41	462.06
LakView	0.05	0.218	0.05	0.212	0.05	0.219
TraNoise	0.17	0.374	0.17	0.377	0.19	0.394
SOCIAL-ECONOMIC VARIABLE						
P_White	31.85%	20.80%	31.48%	20.78%	33.94%	20.29%
M_Income	58873.57	21117.36	59095.75	21310.10	60273.05	21918.06
STRUCTURAL VARIABLE						
LotSize	5759.78	2522.431	6058.02	3043.02	5683.21	2191.273
TotFinished	1218.56	441.900	1285.03	481.54	1295.99	471.738
TotBasement	669.75	480.527	692.76	511.17	627.32	484.346
Bedrooms	3.12	1.068	3.22	1.059	3.28	1.118
Age	54.82	29.413	56.13	30.861	62.80	33.129
Condition	3.39	0.620	3.32	0.585	3.48	0.695
BuiGrade	6.73	0.687	6.80	0.730	6.84	0.763

CHAPTER 6 MODEL RESULTS

Regression models are conducted for properties of the three sites in pre-during-after construction periods. Comparisons among different properties and across time periods are conducted.

In the study, linear functional forms are employed in regression models. Pearson correlation values are tested to examine if there are multi-collinearity problems among selected variables. Variance inflation factor (VIF) is examined to quantify the severity of multi-collinearity. Some variables are dropped or their measurements are adjusted if they are correlated with each other. The F test results suggest that housing price could be explained as the integrated influences of identified variables. The adjusted R square is examined to see the proportions of variations in housing price explained by the variations of identified variables. Coefficients and significance level of each variable are demonstrated and discussed as the following.

6.1 Pre-Construction Period

Pre-construction period is from 1996 to 2001. There are totally 519 valid data applied to pre-construction period model. The adjusted R square shows that the model can explain 52.1% variations in housing price. VIF of variables shows there is no serious multi-collinearity problems.

Using distance band of 0.75-1 mile from station as reference group, distance dummy variables have no statistical significance influence on housing price, but it demonstrates a decline tendency for properties located within 0.25 miles to station and an increase tendency for properties located farther. Mean price of properties located within 0.5-0.75 miles might be about

$25268 lower than that located within 0.75 to 1 mile from the future location of the light rail station. All of the coefficients are negative, indicating that there might be no obvious benefits for locating near the future location of the light rail station, which is understandable because there is no light rail station and TOD at this time. See Figure 6-1 of Unstandardized Coefficients of Distance Dummy Variables.

Four locational variables including intersection number, distance to nearest commercial land uses, Lake Washington view, and traffic noise have statistical significant impacts on property values. Every additional intersection is associated with around $745 increase in housing price. Every one feet closer to commercial land uses results in $26 lower value in housing price. Housing price of properties with Lake Washington view is around $160742 higher than those without lake view. Housing price of properties affected by traffic noise is about $43450 lower than those without traffic noise nuisances. Distance to nearest park, freeway, and Lake Washington do not have statistical significant impacts on property values. In terms of structural variables, many of them have statistical significant impacts at 99% level of confidence. With every one square feet increase in lot size, total finished area above grade, and total basement, housing price increases by $18.483, $131.686, $64.158, respectively. With every one level improved in building grade, housing price increases by $45325.623. The impact of number of bedrooms is statistical significant at 95% confidence level. Every additional bedrooms is associated with $17085 decrease in housing price, which might result from decrease in bedroom size under the control of total square footage of the building. Variables of building age and condition do not have statistical significant influences on property values. As for social-economic variables, percentage of white and median household income do not have statistical significant influences on property values, either.

Comparison of standardized coefficients reflects the different influences of identified variables to housing price. The most influential variables are structural variables, including lot size and total finished area above grade. See Table 6-1 of Regression Results of Pre-Construction Period.

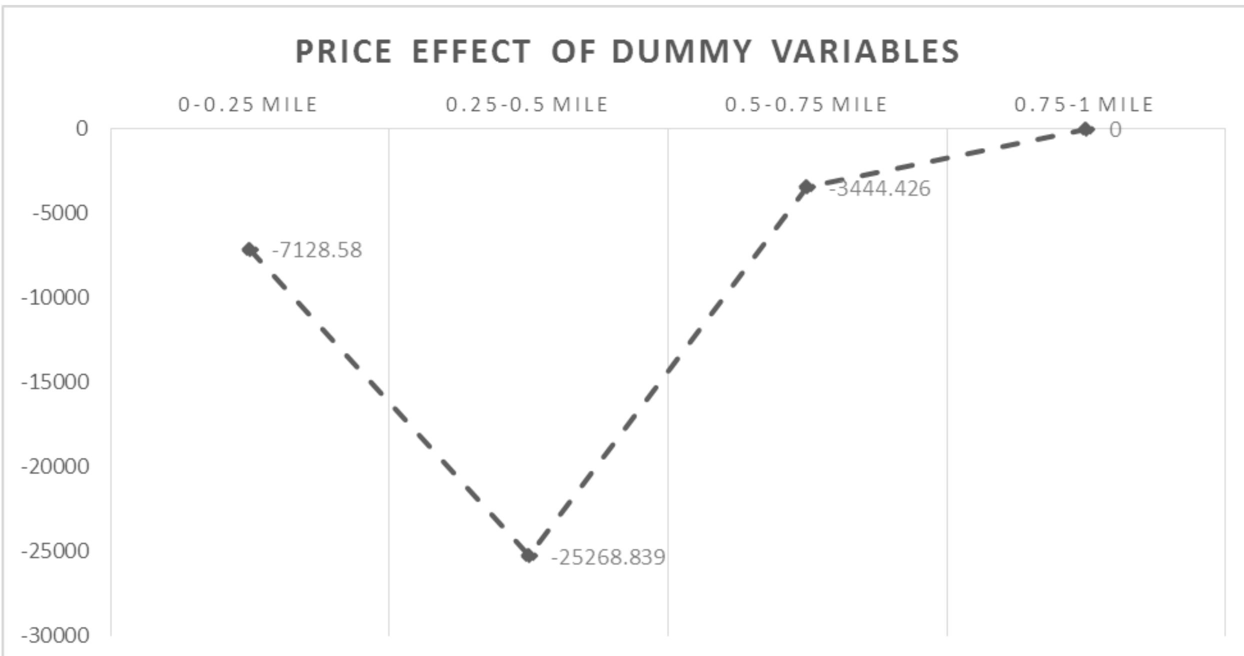

Figure 6-1: Unstandardized Coefficients of Dummy Variables for Before-Construction Periods

Table 6-1: Regression Results of Pre-Construction Period

Pre-Construction Period (1996-2001)	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-303701.942	98001.758		-3.099	.002		
TOD Explanatory Variables							
D_Dummy1	-7128.580	26883.678	-.009	-.265	.791	.752	1.330
D_Dummy2	-25268.839	19045.479	-.056	-1.327	.185	.528	1.893
D_Dummy3	-3444.426	16105.083	-.008	-.214	.831	.598	1.673
Locational Variables							
Intersections	746.916	351.335	.077	2.126	.034	.708	1.413
D_Park	-12.451	10.246	-.039	-1.215	.225	.915	1.093
D_Freeway	5.391	4.850	.068	1.111	.267	.247	4.054
D_Lake	-3.648	3.863	-.049	-.944	.346	.348	2.873
D_ComUse	26.253	15.356	.065	1.710	.088	.647	1.546
LakView	160742.691	33124.936	.178	4.853	.000	.689	1.452
TraNoise	-43450.648	17199.368	-.082	-2.526	.012	.871	1.148
Structural Variables							
LotSize	18.483	2.799	.236	6.604	.000	.723	1.383
TotFinished	131.686	19.079	.295	6.902	.000	.507	1.972
TotBasement	64.158	15.171	.156	4.229	.000	.678	1.475
Bedrooms	-17085.367	7453.998	-.092	-2.292	.022	.568	1.759
Age	-178.627	265.519	-.027	-.673	.501	.591	1.692
Condition	2691.447	10566.171	.008	.255	.799	.841	1.190
BldgGrade	45325.623	12995.125	.158	3.488	.001	.453	2.209
Social-Economic Variables							
P_White	-502.137	528.511	-.053	-.950	.343	.298	3.354
M_Income	.434	.388	.046	1.117	.265	.535	1.867

6.2 During-Construction Period

During-construction period is from 2002 to 2009. There are totally 2486 valid data applied to during-construction period model. The adjusted R square shows that the model can explain 42.5% variations in housing price. VIF of variables shows there is no serious multi-collinearity problems.

Using distance band of 0.75-1 mile from station as reference group, distance dummy variables have no statistical significance influence on housing price, but it demonstrates a decline tendency for properties located within 0.50 miles to station and an increase tendency for properties located farther. Mean price of properties located within 0.25 miles might be about $9101.199 higher compared with properties located in 0.75-1 mile distance band, indicating that the construction of TOD might generate premiums of properties right adjacent to it. Mean price of properties located within 0.25-0.75 miles and 0.5-0.75 miles might be about $3717.32 and $11252.19 lower. See Figure 6-2 of Unstandardized Coefficients of Dummy Variables for During-Construction Periods.

Three locational variables including intersection number, distance to freeway, and Lake Washington view have statistical significant impacts on property values. Every additional intersection is associated with around $414.8 increase in housing price. Every one feet closer to freeway results in $9.587 lower value in housing price. Housing price of properties with Lake Washington view is around $235128 higher than those without lake view. Distance to nearest park, commercial land uses, and Lake Washington do not have statistical significant impacts on property values. The impact of traffic noise is not statistical significant at this time. In terms of structural variables, most of them have statistical significant impacts at 99% level of confidence, including lot size, total square footage of finished area above grade, total basement, bedrooms number and building grade. The impact of building condition is statistical significant at 95% confidence level. With one level improved of building condition, housing price increases by around $18611. Variables of building age does not have statistical significant influences on property values. As for social-economic variables, median household income does not have statistical significant influences on property values, while percentage of white greatly affects property values at 99% confidence level.

The most influential variables are the same as pre-construction periods, including lot size and total finished area above grade, with standardized coefficients beta value over 0.2. See Table 6-2 of Regression Results of During-Construction Period.

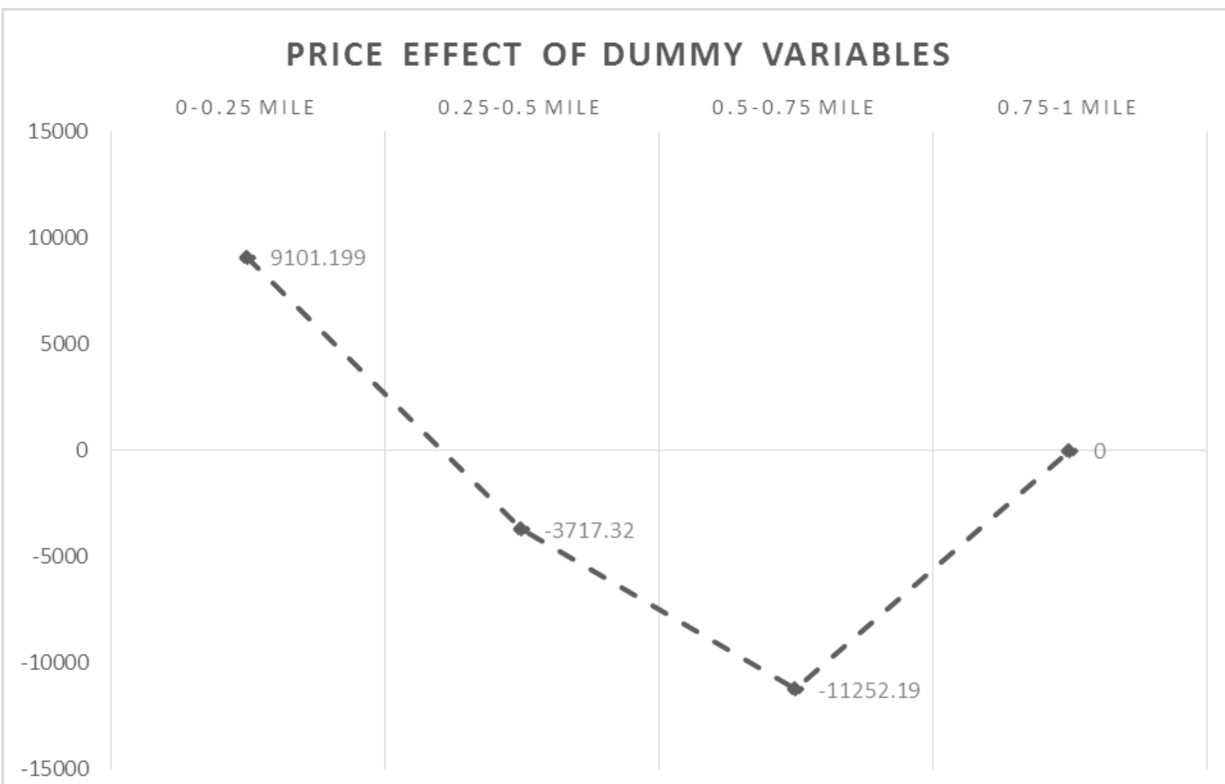

Figure 6-2: Unstandardized Coefficients of Dummy Variables for During-Construction Periods

Table 6-2: Regression Results of During-Construction Period

During-Construction Period (2002-2009)	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-471376.737	63593.386		-7.412	.000		
TOD Explanatory Variables							
D_Dummy1	9101.199	18233.958	.009	.499	.618	.775	1.291
D_Dummy2	-3717.320	12162.110	-.006	-.306	.760	.561	1.784
D_Dummy3	-11252.190	10641.260	-.020	-1.057	.290	.619	1.617
Locational Variables							
Intersections	414.800	244.370	.031	1.697	.090	.690	1.449
D_Park	-4.161	6.611	-.010	-.629	.529	.929	1.076
D_Freeway	9.587	3.304	.089	2.901	.004	.244	4.093
D_Lake	2.845	2.546	.028	1.117	.264	.373	2.681
D_ComUse	11.045	9.800	.021	1.127	.260	.697	1.435
LakView	235128.865	22469.453	.189	10.464	.000	.713	1.403
TraNoise	-1115.063	11320.061	-.002	-.099	.922	.887	1.127
Structural Variables							
LotSize	19.972	1.507	.230	13.250	.000	.768	1.303
TotFinished	129.929	12.018	.237	10.811	.000	.482	2.074
TotBasement	48.159	9.288	.093	5.185	.000	.716	1.396
Bedrooms	-19815.510	4889.817	-.079	-4.052	.000	.602	1.661
Age	40.414	169.798	.005	.238	.812	.588	1.701
Condition	18611.493	7346.748	.041	2.533	.011	.873	1.145
BldgGrade	56345.004	8248.155	.156	6.831	.000	.446	2.243
Social-Economic Variables							
P_White	1129.348	357.376	.089	3.160	.002	.293	3.416
M_Income	.198	.243	.016	.814	.416	.604	1.657

6.3 After-Construction Period

After-construction period is from 2010 to 2016. There are totally 438 valid data applied to after-construction period model. The adjusted R square shows that the model can explain 58.9% variations in housing price. VIF of variables shows there is no serious multi-collinearity problems.

Using distance band of 0.75-1 mile from station as reference group, dummy variable of 0.5-0.75 mile band show significant influence at 95% level, while the other two have no statistical significance influence on housing price. According to unstandardized coefficients, mean price might be $6273 higher within 0-0.25 mile band, $33432 higher in 0.25-0.5 mile band, and $15333 higher within 0.5-0.75mile band, compared with that of 0.75-1 mile band. The results suggested that properties located within 0.25-0.5 mile from station might get largest benefits from TOD. For properties right adjacent to station, within 0.25 mile, TOD dis-amenities might have great impacts. As properties move farther away from station, from 0.5 mile to 1 mile, TOD impacts might decrease gradually. See Figure 6-3 of Unstandardized Coefficients of Dummy Variables for After-Construction Periods.

Four locational variables including distance to freeway, Lake Washington, commercial land uses, and Lake Washington view have statistical significant impacts on property values. With one foot closer to freeway, housing price decreases by around $38.085. With one foot closer to Lake Washington and commercial land uses, housing price decreases by $22.955 and $45.445 separately. Housing price of properties with Lake Washington view is around $81354 higher than those without lake view. Impacts of intersection number, distance to nearest park, traffic noise are of no statistical significant. In terms of structural variables, all of them have statistical significant impacts at 99% level of confidence except for building age. With one square foot increase of lot size, total finished area above grade, and total basement area, housing price increases by around $10. 81, $96.1, $75.1, respectively. Similar to previous two periods, bedrooms number has a negative impact on housing price. Condition and building grade have significant influences on property values: with one level improved, housing price increases by around $22499 and $51718. Social-economic variables have statistic significant influences on property values at 90% confidence level. Different from previous two periods, the most influential variables are locational variables of distance to freeway and Lake Washington. See Table 6-3 of Regression Results of After-Construction Period.

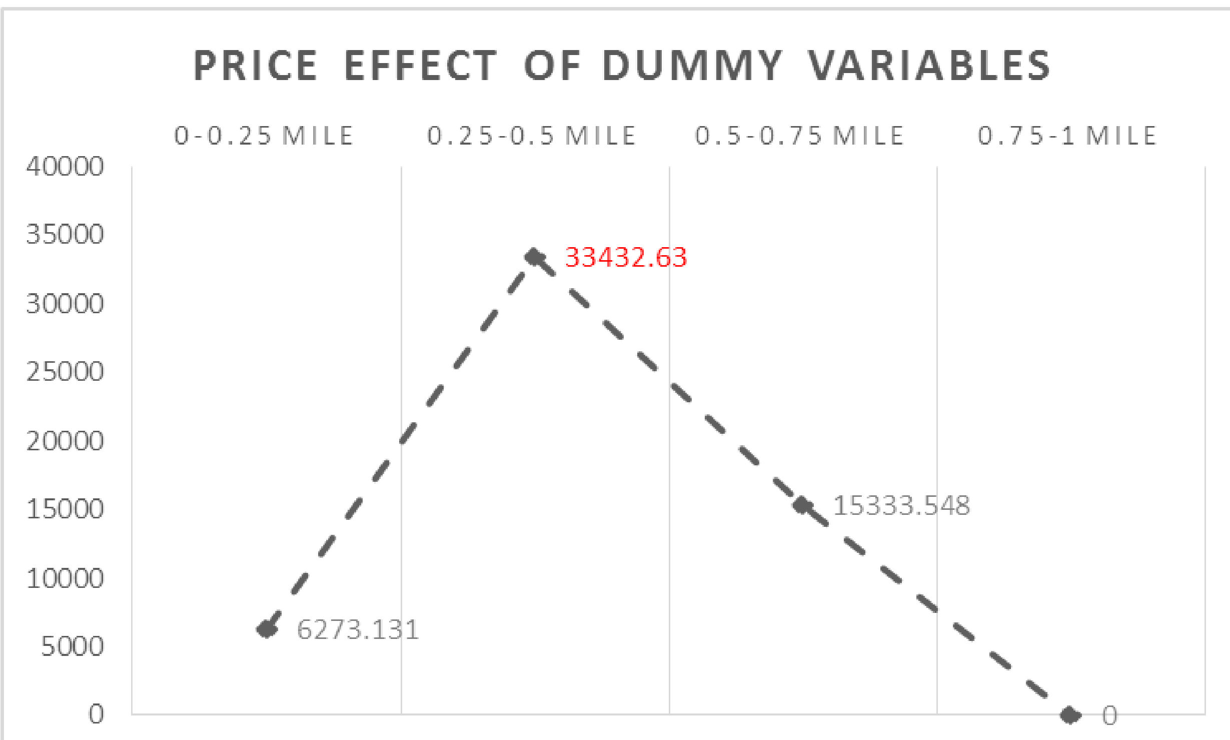

Figure 6-3: Unstandardized Coefficients of Dummy Variables for After-Construction Periods

Table 6-3: Regression Results of After-Construction Period

After-Construction Period (2010-2016)	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-611643.552	88459.807		-6.914	.000		
TOD Explanatory Variables							
D_Dummy1	6273.131	26902.199	.008	.233	.816	.807	1.239
D_Dummy2	33432.630	16714.555	.082	2.000	.046	.553	1.807
D_Dummy3	15333.548	14482.530	.043	1.059	.290	.582	1.717
Locational Variables							
Intersections	41.486	339.541	.005	.122	.903	.632	1.582
D_Park	-9.794	9.757	-.033	-1.004	.316	.883	1.133
D_Freeway	38.085	4.544	.538	8.381	.000	.228	4.387
D_Lake	22.955	3.509	.338	6.542	.000	.352	2.845
D_ComUse	45.445	14.442	.119	3.147	.002	.654	1.528
LakView	81354.772	29458.637	.101	2.762	.006	.702	1.424
TraNoise	4696.347	14528.802	.011	.323	.747	.889	1.125
Structural Variables							
LotSize	10.809	2.761	.135	3.915	.000	.796	1.256
TotFinished	96.100	17.450	.257	5.507	.000	.430	2.325
TotBasement	75.167	13.359	.207	5.627	.000	.696	1.437
Bedrooms	-17363.197	6387.841	-.110	-2.718	.007	.571	1.751
Age	-188.216	223.059	-.035	-.844	.399	.534	1.874
Condition	22499.738	8425.759	.089	2.670	.008	.849	1.178
BldgGrade	51718.343	11298.130	.224	4.578	.000	.393	2.548
Social-Economic Variables							
P_White	110754.937	48645.610	.128	2.277	.023	.299	3.345
M_Income	.548	.318	.068	1.722	.086	.599	1.669

CHAPTER 7 CONCLUSION

The study seeks to investigate the impact of transit-oriented development (TOD) on residential property values using the case of Link light rail TOD in Seattle. Different from previous studies, which decompose TOD impact into constituent parts, the study captures the integrated influence and analyzes price effects in pre-during-after construction periods.

Hedonic pricing method is employed to analysis relations between identified variables. Single-family housing price is studied for representing residential property value. TOD proximity is measured as dummy variables, which are applied as major independent variables. Relevant structural characteristics, locational conditions, and social-economic attributes are identified and controlled in regression models.

Model results suggest that TOD has significant positive impacts on values of residential properties that are located within 0.25-0.50 mile from the station after construction completed. In addition, regression outcomes are different across time periods. In pre-construction period, it indicates that housing price might increase first and then decrease as distance to the location of future station increases, but the relationships are not statistically significant; in during-construction period, similar to pre-construction period, TOD impacts are not statistical significant, but residential properties located within 0.25 mile might benefit from TOD construction to some degree: mean value of housing price might be around $9000 higher than that of properties located within 0.75-1 mile from the station. In after-construction period, TOD has significant positive impacts on values of residential properties located within 0.25-0.50 mile from the station: mean value of housing price is $33432 higher than that of properties located within 0.75-1 mile from the station. For properties located less than 0.5 mile but more than 0.25

mile (and hence reasonably distant from conceivable negative effects of rail transit, such as noise and intrusion of strangers), housing price might increase as TOD proximity increases; for properties located further than 0.5 mile, housing price might decrease as TOD proximity decreases.

There are some limitations in the study. First, the study does not take control of factors affecting housing price comprehensively. This is partially due to limitation in data accessibility. Locational conditions are calculated based on current situations instead of situations at the transaction time. Social-economic characteristics are extracted from American Community Survey 5-year (2010-2014) data rather than data of transaction time. This may result in inaccuracy reflection of actual situation. In addition, it is hard to consider and include all factors affecting housing price, and some of the missing variables, such as school quality and crime rate, might be important. Secondly, the study uses Link light rail TOD in Seattle as a case study to capture the integrated impacts of TOD. Since the implement of Station Area Overlay legislation and construction of TOD are based on actual situation of Seattle, the results of the study might not be applicable to TOD in other places with other transit types.

While the study makes use of all three selected sites to analysis the integrated impacts of TOD on residential properties, further studies could explore more on individual TOD impact on each site. TOD characteristics could be quantified and price effects could be compared among different TODs to investigate the internal mechanism, which would be beneficial to future policy making in relation to TOD programs.

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