The Impact of Transit-Oriented Development on Residential Property Value in King County, WA

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Abstract

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Transit-Oriented Development (TOD) has long been a powerful tool for improving sustainable urban development. A well-designed TOD project enhances the accessibility to different kinds of activities, decreases transportation cost, and increases the travel comfortable level, thereby expanding the willingness to pay for the properties around it. This study measures the impact of Transit-Oriented Development on single-family property value within 1.5 mile radius around Renton Transit Center, a TOD project implemented 18 years ago in King County, WA. Using time-series Hedonic Price Analysis (HPA), results of this study corroborate the mainstream view that TOD has premium effects on surrounding property values. Controlling other variables affecting housing price, increasing the accessibility to the Transit Center by one standard deviation distance (1890 feet, or about 0.36 mile) is associated with an 11% increase of the housing price during TOD-construction time. In post-TOD time, increasing the accessibility by one standard deviation distance (1781 feet, or about 0.33 mile) is linked to a 13% increase of the housing price. Results for time-series dummy variables show that properties sold at a lower price in pre-TOD time than those after TOD took into effect. Then, Hedonic Method is used for three time intervals of before-TOD, during-TOD, and post-TOD. Results show that the insignificant influence of TOD accessibility before TOD operation becomes significantly positive after TOD took place. However, the premium effect of TOD could be reduced due to TOD-related nuisance. Properties located in areas with high percentage of commercial uses and very compact street network systems were sold at a discount. This suggests that besides benefiting from station accessibility, station area properties may also have suffered from TOD-related nuisance that can reduce the benefits to some extent. Findings suggest that local government under fiscal stress could generate additional revenue

source through innovative TOD projects and programs, yet to find an appropriate strategy for mixed land use development near the station also needs to be considered.

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

The U.S. has faced enormous sustainable challenges since the last century. Perhaps the most obvious challenge was turning from mass transit to a car-dependent society. Beginning after World War II, total annual passenger trips of public transportation in U.S fell by 69%, from 22.3 billion in 1945 to only 8.0 billion in 1975 (John Pucher, 2004). Together with substantially decline of public transportation ridership, is the rapidly increase of private car ownership, energy consumption, and environmental pollution. State and local government began to see this, realized that they could do something to improve public transportation. In the approximately 30 years after 1975, state and local expenditures in public transportation rose from $3.2 billion to $22.8 billion, the total annual passenger trips only rose from 8.0 billion in 1975 to 9.5 billion in 2001 (John Pucher, 2004). This trend of rising state and local investment in public transportation has continued in the last decades, but public transportation in U.S still facing challenges.

Solving transportation problem is not simple, and not only lie in improving public transportation. Perhaps the most fundamental underlying source for concomitant decline in mass transit service is the dispersed low-density suburban development –urban sprawl. Therefore, encouraging transit-oriented development (TOD) - a compact, mixed-use development near transit facilities with high-quality walking environment is a new approach to solve the long-term sustainable challenge. The State of California was the pioneer in implementing large TODs. From 1990 to 2000, California invested approximately 14 billion dollars of state funds on mass transportation programs, in result, 21 TOD projects have been implemented over 15 years (California Department of Transportation, 2002). From 2004 to 2014, the Federal Transit Administration (FTA) allocated $18.9 billion to build new or expanded transit systems which involve an important goal of promoting TOD through the Capital Investment Grant program (United States Government Accountability Office, 2014).

Transit-Oriented Development is a solution to improve transportation system, reduce carbon footprint, and improve equity by providing more residents with good opportunity to housing, jobs and services (Cervero et al., 2004). The benefit of being accessible to various kind of services can get capitalized into market value of land and property. Therefore, TOD could be development-based incentive to capitalize land value by selling or leasing land to explore development opportunities around transit station areas. The increases of land value due to public investment in infrastructure and changes in land use regulations could generate more revenue source which could be used to further finance TOD projects without significant fiscal distortion (World Bank Group, 2015). The increasing land value may attract more commercial and service activities in the station areas, thus further increase land value, promote employment, and shaping the city's vibrancy.

Planning is a process involving values of different stakeholders, planning for Transit-Oriented Development is also the case. Stakeholders who work to promote the monetary value of land, including bankers, lawyers, real estates, developers, and local government, are interested in future profits generated by TOD. On the one hand, it is essential for almost all financial decision making. On the other hand, since TOD generally entails higher construction costs and accompanying risks, which could inhibit stakeholders pursuing these projects, therefore knowing how much future profit that can generate by TOD to offset the investment costs is very important. Moreover, since diverse groups' interests are often interdependent in planning process, particular stakeholders' interest in promoting land values are corresponding with environmentalists encouraging less carbon emission, sharing with commuters promoting better public transit services, and community residents seeking better outcome of equity. Thus, this thesis may also improve the overall outcome, satisfying people with other perspectives by in particular addressing some stakeholders' interests.

This thesis is to give an empirical case study about the extent, both in time and space, a completed TOD project fulfilled the promise of residential property value capitalization in Seattle Metropolitan Area, and which TOD components (transit accessibility, mixed land use, and walkable pedestrian design) are more beneficial to land price than others, in order to guide better investment decision making.

1.2 PURPOSE AND STRUCTURE

The leading research question of this research is the underlying mechanism of TOD on surrounding residential property value, in specifically:

1) How did Transit-Oriented Development affect residential property value in previous studies?

2) Have TOD changed single-family housing price in my study area?

3) To what extent, both in time and space, a completed TOD project play a role on capitalizing residential property value? (Whether people are willing to pay a premium for living close to transit stations with TOD patterns? Did housing price around TOD show any difference before and after TOD took into effect?)

This thesis began with a review of existing literatures to identify factors that influenced land price and property value as rationales to build a conceptual model. A review of significant determinants in previous studies served as basis of variable selection in this study.

Then, a case study of a TOD project in King County, WA was conducted. Time-series Hedonic Price Analysis (HPA) was used to identify how specifically TOD components have improved or restrained residential property value within different range of distance around the transit stations while controlling other factors affecting housing price. Also, before-during-after experimental design was then used to measure whether the premium of proximity to TOD are different during three periods of time: before TOD construction, during TOD construction, and after TOD construction. Finally, conclusion and policy implications were given.

CHAPTER 2 LITERATURE REVIEW

2.1 PROPERTY VALUE CAPITALIZATION FROM TOD

While there is no universally accepted definition of TOD, it is generally composed of many common parts, including transit accessibility, mixed use of land near transit station and pedestrian oriented design (Metropolitan Atlanta Rapid Transit Authority, Maryland Transit Administration, Bay Area Rapid Transit Authority, Washington Metropolitan Area Transit Authority, and King County Metro). These components working together and in result enhance the accessibility to different kinds of activities, decrease transportation cost, and also increase the travel comfortable level, thereby expand the willingness to pay for the properties located around it.

Classic economics theories proposed that the maximum amount a land user can pay for the land in a particular location is determined by amenities of the land. Back to 1826, Von Thunen (1826)'s Model illustrates that transportation saving is the determinant of land rent, explains why land prices are higher in some locations than in others. Alonso (1964) also proposed that the development of transportation infrastructure and the resulting drop in transportation costs and increase in accessibility levels are closely related to changes in housing values. These statements justify that why being near TOD would enhance the surrounding housing price.

The premiums of TOD on property value around station area could be disintegrated into several parts:

- First, the introduction of transit service into the neighborhood increases travel options for residents and employees of the area and can reduce travel time to the CBD and other activity centers (Fejarang, 1994). It is the increase of transportation accessibility that transfers into land values.
- Second, one of important TOD characteristic – high degree of mixed land use near station area largely enhances local convenience to different kinds of non-residential daily activities, such as shopping, schools, park and recreation within walking distance. The increasing in proximity and convenience to other non-residential activities has been linked to shorter daily travel distances, lower vehicle trip rates, and fewer total vehicle miles of travel (Ewing and Cervero, 2010). It is this mixed-use advantage that being capitalized into land values.

- Third, another component of transit-oriented development for most project is pedestrian friendly design, which could also affect housing prices. Typically, interconnected streets and smaller blocks are more likely to attract home buyers to pay a premium for their houses than large blocks and cul-de-sacs street design (Bartholomew and Ewing, 2011).
- Fourth, better transit services, proximity to non-residential activities and pedestrian friendly design would attract more population, as well as new investments and businesses thereby creating new employment around station area. The revitalizing economics will spur land values. This effect is largely redistributive, since the relative gains around transit stations are matched by relative losses for properties and businesses that lie away from stations (Robert Cervero, 2004).

Moreover, sometimes there is double-counting influence of these multiplicity of benefits (Robert, Cervero, 2004). Therefore, one cannot look at these effects separately, because they are coordinate and mutually reinforcing, and the overall premium of TOD is always larger than simply adding the value from each components.

However, we must have a clear picture of the dual nature of these influences. Being too close to transit station sometimes will not enhance, but negatively affects housing price. Same thing is that being too proximity to the center of non-residential activities would also decrease property value around it though the convenience to reach commercial activities provided by mixed land uses are favorable to housing market. These phenomena show that property value influenced by TOD vary considerably by settings, and also by how different home buyers trade-off between the advantages and disadvantage of different components of TOD, and between the benefits of overall TOD effects and the influences from other variables such as social-economic condition changes. For example, a trade-off that people frequently make is between the nuisance of station area parking lot and the accessibility to station. People dislike being too close to parking lot around transit stations. A study has suggested that the prices of homes in park and ride station areas suffer a 1.9 percent price decrease for over 10-year period (Kahn, 2007). Same thing is for nonresidential land uses. An early study from Grether and Mieszkowski (1980) analyzed the impacts of nonresidential land uses on prices of housing in New Haven, Connecticut, indicating that proximity to nonresidential area actually have negative price effect. Li and Brown (1980) found that the impacts of the negative externalities decrease more rapidly with distance than the positive effects of accessibility. As a result, land price and property value will adjust to achieve a locational equilibrium. This is why sometimes properties located at least some distance away from TOD have significantly higher values than those in the station area.

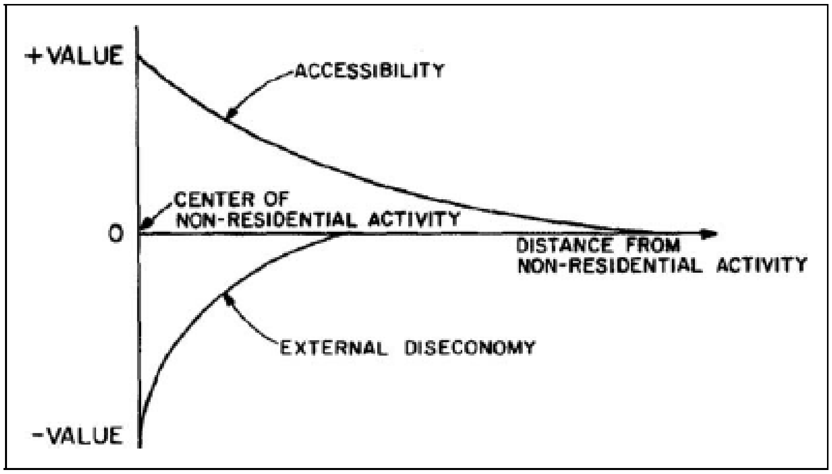

Figure 1 - Positive and negative influences on residential land prices of proximity to non-residential land uses (source: Li and Brown, 1980)

A great many studies after 1990 measure the effect of transit adjacency on property values. Table 1 to 3 are the summary of some of literatures on this topic. The study areas, transit types, target properties, measuring timeframes varies, and the results are largely different. Among these literatures, 8 are from American, 3 from Asian, and 1 from UK. The target properties include office and commercial properties, block land value, as well as residential properties or land values. Transit types include rapid transits, light rails, high speed rails and bus stops. All of them are using Hedonic price model, a typical method for housing price analysis as illustrated in Chapter 4 though specific model transformations are different. Most of them are cross-sectional, and two did before-after analysis. Some compared home prices located within certain bands around transit stations, e.g., within 0.25 mile or 1 mile to stations. Some simply used distance to stations as a single variable to measure how the distance to stations affects property values.

Table 1 - Summary of studies on impact of TOD proximity on property value – 1)

Reference	Study Area	Target	Transit Type	Method	Measuring Timeframe	Sample size	Major significant variables	Radius	Premium
McDonald and Osuji, 1994	Chicago	block land value	Rapid Transit Line	Semi-log hedonic regression, before-and-after comparison	compare the year of 1980 and 1990	79 blocks observations for 1980 and 79 for 1990	distance to transit station (+), distance to major shopping center (-), population density (-), percent black population (-)	0.5 mile	An increase of 17% in residential land value within 0.5 mile of the station sites can be attributed to proximity to transit station.
Bowes and Ihlanfeldt, 2001	Atlanta	sale price of single-family homes	MARTA (rapid transit)	Semi-log hedonic price model	from 1991-1994	22,388 sales price	MARTA one mile (-), MARTA two mile (-), highway interchange two mile (+), highway interchange three mile (+), percentage of black (-), housing structure	5 radius - within 0.25, 0.25-0.5, 0.5-1, 1-2, and 2-3 mile to station	Properties within 0.25 mile from a rail station are found to sell for 19% less than properties beyond 3 miles from a station. However, properties that between 1 and 3 miles from a station have a significantly higher value compared to those farther away.
Cervero and Duncan, 2002	Santa Clara County, CA	office, commercial, light industrial properties	light rail transit and commuter rail transit	hedonic price model	In 1998 and 1999	1,197 parcels, 55.4% commercial, 41.5% offices, banks and clinics, 2.8% industrial	CalTrain Station within 1/4 mile_dummy (+), LRT station within 1/4 mile_dummy (+), regional labor force accessibility (+), downtown San Jose (+), labor force density (+)	1/4 mile around LRT and CalTrain stations	Commercial, office and light industrial parcels located within 1/4 mile radius around Caltrain stations worth more than $25/ft^2 than otherwise comparable properties away from stations; within 1/4 mile of LRT worse $4/ft^2 than otherwise comparable properties.
Andersson, Shyr, and Fu, 2008	Tainan, Taiwan	residential property transaction price	High-speed railway	log-linear, semi-log, Box-Cox hedonic price model	cross-sectional in 2007	1550 residential property transaction record	distance to CBD (-), floor area (+), lot size (+), house age (-), shop use (+), street frontage (+), road width (+), commercial zone (+), college-educated in district (+)	the whole Tainan Metropolitan Area	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.

Table 2 - Summary of studies on impact of TOD proximity on property value – 2)

Reference	Study Area	Target	Transit Type	Method	Measuring Timeframe	Sample size	Major significant variables	Radius	Premium
Michael Duncan, 2011	San Diego MSA, CA	condomimium unit sale price	San Diego Trolley (light rail)	cross-sectional hedonic price model, using unbiased OLS regression and semi-log form	1996 to 2001	total of 3374 sales of individual condo units, located on 439 parcels	distance to nearest Trolley station (-), slope between the parcel and nearest Trolley station (+), Hectares of land within a 400-metre radius of a parcel dedicated to a park-and-ride lot (-)	within 1 mile of the nearest Trolley station	No statistically perceptible station area premium. But increases in intersection density, increases in people-serving commercial activity or decreases in the steepness of the terrain will enhance the relative value and statistical significance of station proximity.
Mathur and Ferrell, 2012	Ohlone Chenyoweth, San Jose	single family home sale transactions	light rail	Fixed effect ordinary least squares hedonic regression, in log form, before-on going-after comparison	1991-1995 before TOD; 1996-2003 during TOD; 2003-2006 post TOD	779 transaction observations, 131 in before, 421 on-going, and 227 post TOD	distance to TOD only significat for post-TOD period (-), size of house (+), size of lot(+), age of house (-), proximity to freeways (-), population density (-)	1-mile buffer around TOD light rail station	Proximity to TOD did not impact home prices for before-TOD period. However, during the TOD construction period, the homes within 1/8 mile of the TOD were 7.3% higher in price compared to the homes further away. This price differential more than doubled to 18.5% during the post-TOD period.
Ma, Ye, and Titheridge, 2013	Beijing metropolitan area	property price per square meter of apartment homes	11 rail transit lines, and one BRT line	hedonic price model in semi-log form	In 2011	1,695 sample properties	rail station proximity (-), distance to city center (-), distance to the nearest subcenters (-), ratio of commercial and entertainment land use within 400m (+), has elementary school (+), administration fee (+)	built-up area within the 6th Ring Road of Beijing	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	sale price of single-family detached home	light rail	semi-log hedonic price model	cross-sectional, in 2009	20,149 single-family home sales	distance to light rail station dummy variables, distance to highway exit dummy variables, presence of pool (+), age of house (-), distance to CBD (-)	in 300m bands out to 3000m to station	10 bands in 300m bands out to 3000m, each premiums property value for 3.5%, 5.0%, 6.1%, 5.2%, 4.8%, 2.5%, 3.8%, 2.8%, 2.5%, and 1.6%, where 900m reach the peak

Table 3- Summary of studies on impact of TOD proximity on property value – 3)

Reference	Study Area	Target	Transit Type	Method	Measuring Timeframe	Sample size	Major significant variables	Radius	Premium
Yiming Wang et al., 2014	Cardiff, Wales, UK	property's sale price	bus stops	log-linear hedonic price model	from 2000 to 2009	12,887 sales records	distance to CBD (+), number of bus stops within different radius of walking distances (+), floor area (+), age of the building (-)	6 radius - 300m, 400m, 500m, 750m, 1000m, and 1500m to station	The marginal increase in land values as a result of placing every extra bus stop around a property within 300 meters, 400 meters, or 500m add land value equal to 0.3%.The land value benefit of every additional bus stop within a circular catchment area larger than 500m by radius is about 0.1% of the corresponding property price.
Chen and Haynes, 2015	Beijing-Shanghai, China	market assessment price of housing per square meter by online real estate listing firm	High-speed railway (Beijing-Shanghai high speed Railway Line)	hedonic price model using a robust log-linear regression, a restrictive Box-Cos transformation regression, a	cross-sectional in 2014	1016 randonly selected housing properties from 22 cities along BJHSR line	per capital income (+), floor area ratio (+), population density (+), the status of housing condition (+), distance to HSR station (+/-), distance to city center (-)	properties located within the buffer area of 50km along the line	A 1% increase of the accessibility to a BJHSR station is associated with a 0.197% decline of housing value in capital cities and a 0.078% increase of housing value in noncapital cities, respectively. The effect to capital city is not very significant in different model, but for non-capital cities, the effect is significant.
Kay, Noland and DiPetrillo, 2014	New Jersey to New York City	Median block-group-level residential property valuation provided by online real estate listing firm	New Jersey Transit (NJT) rail system	log-transformed hedonic price model, in semi-log form	cross-sectional in 2013	Total of 451 block groups around 8 stations	distance to neaest study station (-), median household income (+), effective tax rate (-), % of Black or African American (-), Average SAT math score (+)	block groups within a two-mile radius of eight sampled NJT stations	Block groups one mile from a study station are expected to have property values 6.3% lower than block groups one half mile from a study station. Block groups located one and a half miles from a study station are expected to have property values an additional 2.7% lower than those located one mile away, and properties two miles out have a small increase in value.
Yan, Delmelle, and Duncan, 2012	Charlotte, NC	single-family housing values in undevelopded areas	a light rail line	Hedonic Price Analysis in semi-logarithmic form	from 1997 to 2008, divided into four period	Total of 6381 single family properties	Network distance to light rail stations (positive but at decreasing rate), housing structure variables at expected sign	Properties within 1 mile network distance from the stations	Though during four period, the coefficients are positive, but decreases from 12% to 5% which means for each time period, as network distance to the light rail increases, so do housing prices.

Among these literatures, most found that proximity to transit stations leads to property value increase (McDonald and Osuji, 1994; Cervero and Duncan, 2002; Mathur and Ferrell, 2012; Ma, Ye, and Titheridge, 2013; Yiming Wang et. Al., 2014; Seo, Golub, and Kuby, 2014; Kay, Noland and DiPetrillo, 2014). Though similar results are found in different studies, the relative impacts of accessibility to station are also different. Also, since different studies used different forms of regression methods, some interpreted the premium as percentage change of price as a unit increase of distance to station, some interpreted as price elasticity. In addition, some measured distance by series of dummy variables, but the reference groups varies. These reasons make the results of premium difficult to compare. Generally, using otherwise comparable housing outside station area (inconsistent in different studies) as control group, the premium effects of station proximity (on properties located 1/8 to ½ mile distance to station) vary from 3.5% to 25% as these studies show. Cervero (2004) 's meta-analysis showed that price premiums for housing located within a ¼ to ½ mile radius of rail transit station of between 6.4 % and 45 % comparing to equivalent housing outside of the station areas.

However, the statement that proximity to stations has premium effects on property values were not corroborated by the evidence from other studies. Three studies found that there is no statistically perceptible station area premium near station area, one for high-speed-rail in Taiwan, one for light rail in U.S., and one for bus rapid transit in Beijing (Andersson, Shyr, and Fu, 2008; Michael Duncan, 2011; Ma, Ye, and Titheridge, 2013). Some even indicated a negative relationship (Bowes and Ihlanfeldt, 2001; Yan, Delmelle, and Duncan, 2012; Chen and Haynes, 2015). However, among these literatures, some found proximity to stations will increase property value only if conditional upon other variables such as intersection density, commercial activity, intersection density, distance to city center, and income level of neighborhoods (Michael Duncan, 2011; Ma, Ye, and Titheridge, 2013). Some suggested that though the negative relationship exists between proximity to station and housing price, the coefficients became smaller during TOD operation time comparing with before-TOD time (Yan, Delmelle, and Duncan, 2012). These mean station proximity still plays a role in increasing property value if not considering other effects.

Previous studies have yielded vastly different results ranging from proximity to station significantly increases property values, to negatively affect property values or have no significant relationship with property value. These different results of previous studies are because of several reasons:

- **First, impacts of station proximity are conditional upon changes of other variables.** Though distance to station matters, as most studies concluded, the relationship is not as simple as a linear function. There is value discount for station nearby properties when diseconomies of station adjacency exceed its economies. Sometimes the comparable property value reach its peak at the intermediate distance to TOD stations. A study found that properties between 1 and 3 miles from a station have significantly higher value than those near or farther away from stations (Bowes and Ihlanfeldt, 2001). Similar result found in another research, indicating that station premium reach the highest level at the distance around 600m to 900m from the stations, and the premium curve is like a well-behaved inverse-U shape (Seo, Golub, and Kuby, 2014). These results mean that people do not judge TOD as a single amenity of accessibility, but trade-off between these amenities and TOD-related nuisances. The accessibility benefits of proximity to station are somewhat offset by other disamenities associated with proximity. Some studies used interaction term in regression model to analysis this relationship, e.g. Duncan (2011)'s study show that in spite of the overall statistical insignificant result of distance to stations, when increase in commercial activities, or decrease in the steepness of terrain, the relative value and significance of station proximity would enhance. Using interaction term, increase in distance to city center or change the location of the property from high-income neighborhood to low- and medium-income neighborhoods will increase the relative value of station proximity (Ma, Ye, and Titheridge, 2013).
- **Second, land values vary considerably by settings.** Three articles did research in rapid growth world, Beijing and Taiwan, found that proximity to stations are not very significant, more or less in some circumstances. For example, in seven of eight models from Andersson et al.'s (2008) research, distance to HSR station is not very significant. Even if tentatively accept the price-distance effect, the amount is no more than a 3% - 4% price premium. Similar results have found in another research that proximity to BRT station is not significantly beneficial to residential property values (Ma, Ye, and Titheridge, 2013). Chen and Haynes (2015)'s research studied submarket in capital cities and non-capital cities, found that a 1% increase of the accessibility to a BJHSR station is associated with a 0.197% decline of housing value in capital cities and a 0.078% increase of housing value in noncapital cities. The reasons why these articles reached these results are complex. In Taiwan, it may because the high ticket prices and entrenched residential location patterns which made HSR accessibility a minor effect on housing price. In

China, the lack of walkable environment in the immediate area of BRT stations is probably a reason. Or it may because of statistical estimation problems.

- **Third, land value premium rates are determined by different transit types.** Properties within a ¼ mile radius of a station in regional commuter rail system command a $25 per square footage premium, while in light rail system show only a $4 per square footage premium (Cervero and Duncan, 2002). Ma, Ye and Titheridge (2013) found that an average price premium of around 5% for properties near rail transit stations, but no statistically significant effects were detected at BRT station areas. Only one among these literatures did research for bus transit, showing that the marginal increase in land values as a result of placing every extra bus stop around a property within 300 meters, or 400 meters, or 500 meters is 0.3% (Wang et al., 2014). Since this measurement is different from using distance as the key variable in most other studies, the effect of bus type TOD in this study is difficult to compare with that of other transit types.
- **Fourth, value premium rates vary according to target markets.** The target markets include single-family home sales price, apartment per unit sales price, block land values, and office, commercial, and light industrial properties. The research did for commercial, office and light industrial found the highest level premium, which is at around 25% price increase than otherwise comparable properties for parcels located within ¼ mile distance to station (Cervero and Duncan, 2002). Duncan (2008)'s research found that for multi-family housing, the premium of proximity to station is 16.6%, three times higher than single-family housing with a premium of 5.7%. These may illustrate that commercial or multi-family home buyer values transit proximity higher than single-family home buyer.

Comparing to large numbers of literatures simply study how transit accessibility affects property value, only a small numbers focus on more of other TOD components such as mixed land use and walkable design. Using data from Portland, Oregon, a study found that home buyers are willing to pay a premium for houses in neighborhoods containing interconnected streets and smaller blocks (Song and Knaap, 2003). Duncan (2011) studied the relationship between street intersections and housing price, suggesting that increase in intersection density will enhance the relative value of station proximity. However, there are also studies with a completely contrary finding. In Andersson et al (2008)'s research in Taiwan, lot size is a positive variable to residential property price near high-speed railway. Another study did for single-family housing price around light rail stations in Pheonix, Arizona also reached the similar result (Seo, Golub and Kuby, 2014).

Among all of these twelve literatures, only a few used variables relating mixed land use. In Andersson, Shyr, and Fu (2008)'s research, locating within commercial zone would positively affect property value. Ratio of commercial and entertainment land use within 400m of property was also proved significantly positive to housing sale price (Ma, Ye, and Titheridge, 2013). Using interaction term, Duncan (2011) found that increases in people-servicing commercial activity would increase significance and relative value of station proximity. These mean other parts of TOD components, including mixed land use and pedestrian design also play a role in property value premium or discount but have always been neglected unlike station adjacency.

2.2 Other factors affecting residential property value

Other factors known to affect residential property value have also been studied a lot. Under hedonic analysis framework by Rosen, the price of house are valued for their utility-bearing attribute or specific amounts of characteristics associated with them (Rosen, 1974). These specific characteristics combining with house were identified together or separately in previous studies. A review of significant determinants in previous studies will serve as a basis of variable selection in this study. Based on existing literatures review, a hypothesis of factors affecting property value and groups of variables of interest are made. Undoubtedly, elements measuring the basic condition of the house such as living area, age of house, house quality, number of bedrooms etc. are important determinants of housing price. These elements have also proved to be significant in almost all previous housing price studies using Hedonic Price Analysis (HPA) in the following part of this Chapter, therefore will not be paid too much emphasis. This part only includes other non-physical structure variables reflected in the price premium or discount of residential property value.

2.1.1 Social and economic related factors

Previous studies have considered social and economic factors such as income, race and owner education level are in relation with housing price. Among all previous studies relating with this subject, race differentiation of residential housing price have been studied a lot especially in early literatures (Bailey, 1966; Lapham, 1971; King and Mieszkowski, 1973; Berry, 1975; Daniels, 1975; Schafer, 1977; Chambers, 1991). Some studies made an absolute conclusion that there are housing "discount" for black residents or blacks are actually receiving a "good deal" in the housing market (Berry, 1975; Follain and Malpezzi, 1981). For instance, Follain and Malpezzi (1981) find statistically significant discounts for black renters in 26 SMSAs (4 premiums, 9 insignificant) and discounts for black owners in 34 SMSAs (5 insignificant). The average discount for blacks is about 15 percent for owners and 6 percent for renters (Follain and Malpezzi, 1981). Studies with an absolute conclusion that there are housing "discount" for black residents are typically assumed that general neighborhood characteristics are invariant.

However, the result of whether blacks pay less than whites for identical housing is not consistent. Most studies after 1970 implied that the reason why blacks pay less for their housing price is because their lower average amenity package. Thus, they began to sophisticatedly analyze neighborhood characteristics and compare the amount of pricing pay by different race for identical housing. After controlling of neighborhood quality and racial composition of neighborhood, studies found household price differentials are more complicate in racial submarket than a single race housing market. A study conducted in 163 census tract in California found that white were willing to pay a premium to live in the relatively segregated white submarket, and a unit of housing space was more expensive in the black rental submarket, while a unit of housing quality cost more in the white rental submarket (Charles B. Daniels, 1973). Brian J. L. Berry's research found that controlling for structures and other characteristics, blacks were willing to pay more to move into white neighborhoods (Brian J. L. Berry, 1975). Another study have found that housing prices are substantially higher in the ghetto and transition areas than in white areas, and black residents nearly always pay more than whites for the same bundle of housing attributes at the same location (Robert Schafer, 1977). Rents for whites in boundary (integrated) areas are about 7 percent lower than rents for black households in these areas (J. R. Follain and S. Malpezzi, 1981). Daniel's research divided housing market into four subcategories, found that for both renters and owners, housing prices are significantly lower in racially transitional neighborhoods than in racially stable ones (Daniel N. Chambers, 1991). All these studies have found that when other condition are equal, blacks pay more than whites for a housing unit in a metropolitan area.

Unlike these studies, some studies even found that no significant relationship between race and housing price. By using census block data of two Chicago Southside areas, Martin J. Bailey (1966) concluded that there is no indication that blacks pay more for housing than do other people of similar density of occupation. Victoria Lapham (1971) compared the price of housing with different dimensions of characteristics to estimate implicit prices of characteristics bought by blacks and whites, also indicating that no significant statistical result proved that there is difference in black and white housing cost.

Age is another social-economic factor in explaining housing price differentiation. Similar to race, different studies also get different result. Early study like Mankiw and Weil (1989) constructed a demand equation to explain that age structure is a major determinant of housing demand, then used time series model to link house demand with housing price therefore link the age with housing price. However, Green and Hendershott (1980)'s working paper on the contrary differs from theirs by using both demand as well as hedonic equation, suggesting that there is only a modest impact of demographic factors and barely perceptible one of age using 1980 Census data.

Perhaps age is associated with household income thus to be a determinant in housing price because youngsters typically bear housing charge burden. Common sense tells us higher income people tend to live in decent neighborhoods associated with desirable neighborhood attributes such as aesthetic quality, and typically properties located in this kind of neighborhood are more expensive than otherwise comparable housing in neighborhood with poor natural or social environmental condition. By using Hedonic Regression method, study have found that median income is positively related with housing price and statistically significant at the 0.05 level to housing price in Boston metropolitan area (Mingche M. Li and H. James Brown, 1980).

Neighborhood with higher household income not only capitalized into housing price, which can result in household income differentiation. Sometimes expensive housing prices will exclude low income households, letting low-income family have no choice but live in predominantly poor living condition neighborhood. Using American Housing Survey from 1991 through 2005 to identify the characteristics of first-time home buyers and their housing choices, Herbert and Belsky (2008) found that low-income home buyers are reflected in a higher propensity to live near commercial or industrial properties than moderate and high income homebuyers.

2.2.2 Other locational related factors

Common sense tells us that for residential property valuation, close to natural amenities, scenic views, lake, and parks typically increases property value, while proximity to highways, industrial district, and airport often devaluates residential property value because of the disadvantages like noise and air pollution.

In terms of the influences of open space, primarily green space on residential property value, studies measured the distance to different types of nearby open areas and found that home value increases with proximity to open spaces (Bolitzer and Netusil, 2000; Troy et al., 2009).

Whereas these studies considered open space as positive amenity to residents, some studies, however, provided that parks sometimes serves as negative role in increasing property value. These studies indicated that open space can be either negatively or positively valued and is affected by its characteristics. Netusil (2005) found that "urban parks" where more than 50% of the park is manicured or landscaped are valued negatively between 200 ft and ½ mile of a property while the "natural parks" where more than 50% is preserved in "natural" vegetation, had no effect of property value. Geoghegan (2003)'s study distinguished protected open space like public parks and developable open space like privately owned land, suggesting that preserved open space surrounding a home increases home value, while developable open space has less significant, or even negative effect on home value. Some studies distinguished "permanent" open space with "developable" open space, found that "permanent" open space actually increases near-by residential land values over three times as much as an equivalent amount of "developable" open space (Jacqueline Geoghegan, 2001).

Some give the reason that why open space sometimes negatively affects residential property value. Troy and Grove (2008) used four hedonic regressions including log-transformed and non-log transformed, found that park proximity is positively valued by the housing market where the combined robbery and rape rates for a neighborhood are below a certain threshold rate but negatively valued where above that threshold. This means sometimes open space is related with crime, thereby devaluating the surrounding property value.

As for the effect of proximity to waterbodies on residential property value, Hedonic Pricing Method have also been used to measure the capitalization of various of waterbodies, including lakes and reservoirs on housing price before. Common findings in most relating studies is that both the size of lake and lake proximity increase residential property value (Lansford and Jones, 1995; Seong-Hoon et al., 2006). Using residential sale price data around three lakes including Lake Washington, Green Lake, and Haller Lake in Seattle, an earliest study found that the value of a property falls with distance from the water (Brown and Pollaskowski, 1977). Lansford and Jones (1995) measured the marginal price valuation of water amenity, found that on average, an aggregation of RA prices, the recreational and aesthetic value for a central Texas lake, composes 15% of the total market price of housing.

Other locational studies, however, focused on public goods such as highways and airports which provide diseconomies to its nearest residents. Studies found that located along a developed highway would result in discount in the value of properties since highway increases traffic noise pollution (Allen, 1980; Langley, 1976; Wilhelmsson, 2000). A metadata analysis reviewed nine empirical studies covering fourteen different housing market samples for North America, suggesting that highway noise discounts housing price in the range of 0.16% to 0.63% decibels, with a mean of 0.40% (Jon P. Nelson, 1982). Proximity to highway have different effects on different types of properties. Proximity to freeway was observed to have an adverse effect on the sales prices of detached single-family residences, but have a positive impact on multifamily residential and some commercial properties (Jason Carey, 2001). Another review of thirteen articles by Nelson (1980) showed that the major reason of the lower property value close to airport zone is aircraft noise (Jon P. Nelson, 1980).

Another locational factor that would enormously influence property value is proximity to Central Business District (CBD). Because land near CBD typically associated with high accessibility to jobs, retails and other services, transportation cost to these activities is much lower if close to CBD. This convenience will drive up the demand for locating near CBD, hence, the land value. Urban economics theory demonstrated that location equilibrium only occurs when different players satisfied with their location choices (Arthur O'Sullivan, 2012). Because land closest to the city center is more expensive than other places, properties with the deepest bid rent curve will occupy that part of land. Therefore, the closer to CBD, the higher land rent and higher property value. Studies have found that when all else being equal, a 1.7 percent decrease in the sales prices of single-family homes for every 10 percent increase in the distance from DC (Geoghegan, Wainger and Bocksteal. 1997). However, the other side is that close to CBD is always correlated with other negative part of nuisance such as high crime rate (S. Mathur, 2008).

2.3 SUMMARY OF LITERATURE REVIEW

This Chapter reviewed studies on TOD and other factors influencing residential property value. Based on these, a brief summary of key points are as follows:

- Transit-Oriented Development is typically composed of transit accessibility, mixed land use near transit station and pedestrian oriented design. These components working together to enhance the accessibility and convenience to different types of activities therefore will increase the willingness to pay for the nearby properties.
- Extensive body of literatures corroborate the statement that transit adjacency have premium effects on residential property value. However, the degree of relative importance of station proximity on housing price varies, which is affected by other variables change, their different settings, target market, as well as transit types.
- There are still a small part of literatures found no significant relationship between TOD and property value increase. But using interaction-term analysis, proximity to station becomes significant to housing price. This means the effect of TOD is sometimes conditional upon other environments.
- Most previous literatures focus more on a narrow part of TOD, i.e., transit accessibility. However, other components like mixed land use and walkable pedestrian design have not been mentioned a lot.
- Most previous works applied cross-sectional Hedonic Regression Analysis approach, only measuring the impact of TOD on properties located at different distance to station. However, longitudinal approach providing more evidence of causality are less used compared with cross-sectional studies.
- Few study did similar research in Seattle metropolitan area, thus how TOD impact residential property value in this area is still an open question.
- Besides TOD-related variables, existing studies measured variables in three categories: 1) physical structure of the building, like size, age, bedrooms; 2) Social-economic characteristics, such as race, age, and income; 3) Locational factors, like close to CBD, close to open space and highways. These studies help to build a conceptual model of factors affecting property values

treated as controlling variables in Hedonic Regression Analysis (HPA). This conceptual model is as follows:

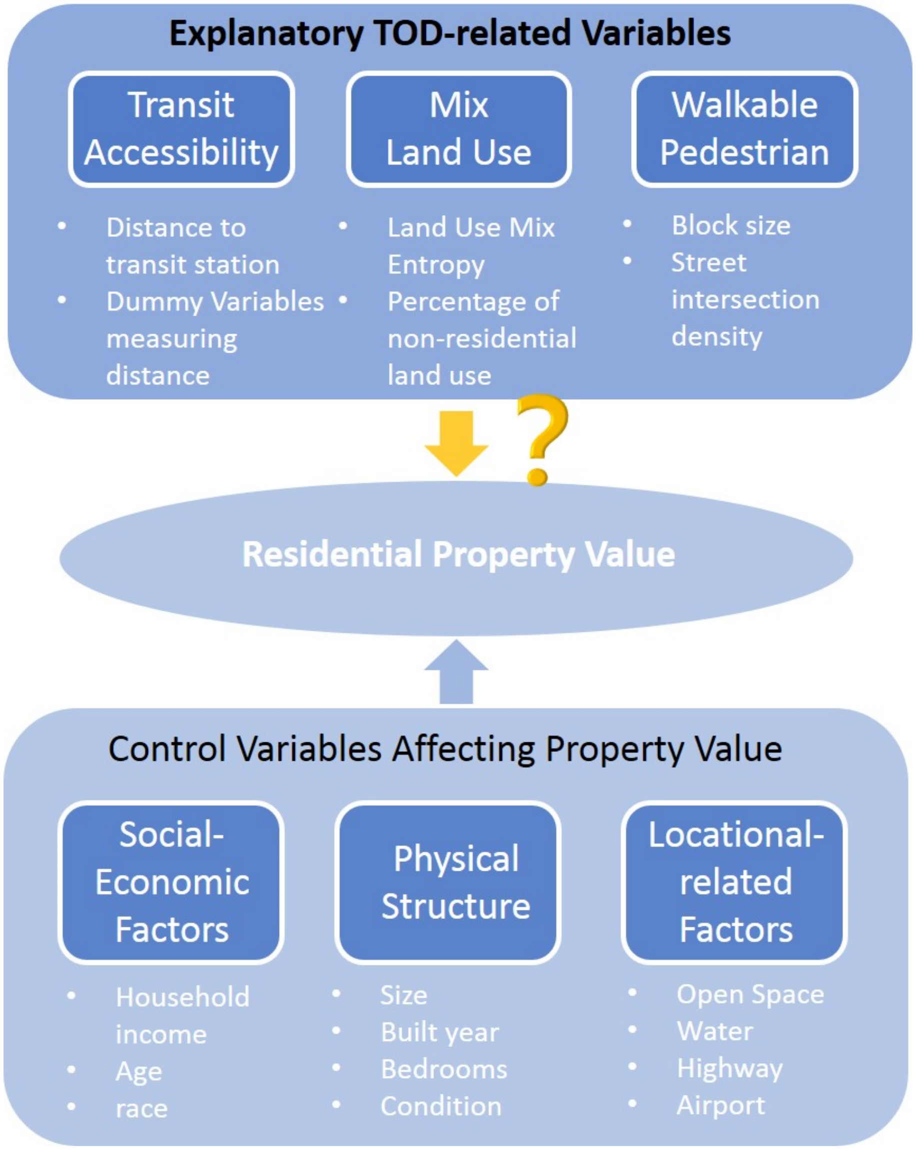

Figure 2 - Conceptual model of factors affecting residential property value

The review of the literature will help design the study presented in the rest of this thesis, which focuses on whether TOD variables impact the price of single-family houses around 1.5 mile distance to a TOD project in Seattle Metropolitan Area while controlling other significant variables identified in previous studies. The reason for choosing single-family properties is because the sample size is large enough within 1.5 mile radius to TOD, and simple to analyze than multi-family properties applying different set of criteria to assess the physical structure condition by Assessor. Using Hedonic Regression Analysis

(HPA), this study will evaluate whether people are more willing to pay a premium near station area, and how much premium they would like to pay if living closer to a transit station under Transit-Oriented Development rather than an otherwise comparable house outside a limited distance to station. Also, this study will analyze housing sale price before, during, and after the TOD construction to provide more statistical evidence of causal relationship between TOD and residential property value.

CHAPTER 3 STUDY AREA

3.1 STUDY AREA SELECTION CRITERIA

The criteria for study area selection is that: 1) A large real TOD project has been took into effect for a long time, at least for 10 years; 2) There are a great many residential properties within one and a half mile radius of the TOD station before and after TOD implementation; 3) The property value have changed overtime; 4) Available data. At first, the Link light rail stations in city of Seattle served as the probable study areas. However, some conditions may hinder choosing light rail stations in Seattle as study area. First, the Link light rail service in Seattle was opened in 2009, the time span do not meet the first criteria. Second, for most Link light rail stations with significant single-family residences within one and a half mile radius of station, such as Bacon hill and Othello, even if did have TOD liked station area plan in 1989, real large TOD project began construction too late, and most are still in construction now. Third, within one and a half mile radius of station, besides the study station, there are other Link light rail stations with TOD-liked components which makes difficult to control the effects of other stations. Thus, I began to search real large TOD project in King County website. In King County, completed TOD projects include Village at Overlake, Renton Transit Center, Downtown Redmond Transit Center, and Northgate. All of them are served by King County Metro Transit (KC Metro). The transit center of downtown Redmond was officially opened in February, 2008, therefore does not meet the time span limitation. In addition, it is also difficult to meet the second criteria. Same condition is for another TOD project -Village at Overlake. Northgate is either not an ideal place for doing this analysis because the transit service was completed late till 2009. Thus, Renton Transit Center, opened and started TOD construction in 1996, served as the study area of this analysis. The target properties are single-family properties within 1.5 mile distance to the Renton Transit Center as single-families are easier to analysis and are with enough sample size.

3.2 STUDY AREA DESCRIPTION

Renton is a city in King County, with a population of 90,927 according to 2010 Census. It is located 11 miles southeast of downtown Seattle, at the southeast shore of Lake Washington and mouth of the Cedar River. It is home to many large manufacturing and companies such as Boeing, which have been the most important employer in Renton since World War II. Renton Transit Center was opened in 1996, and till now, at least 15 Metro transit lines successively serve this station, linking Renton with Seattle, Bellevue, Redmond and other cities in King County. Meanwhile, several multi-family buildings, open spaces, and commercial places have been built during 1996 to 2004 (King County Department of Transportation, 2010).

A timeline of transit-oriented development around Renton Transit Center area is shown in Figure 3:

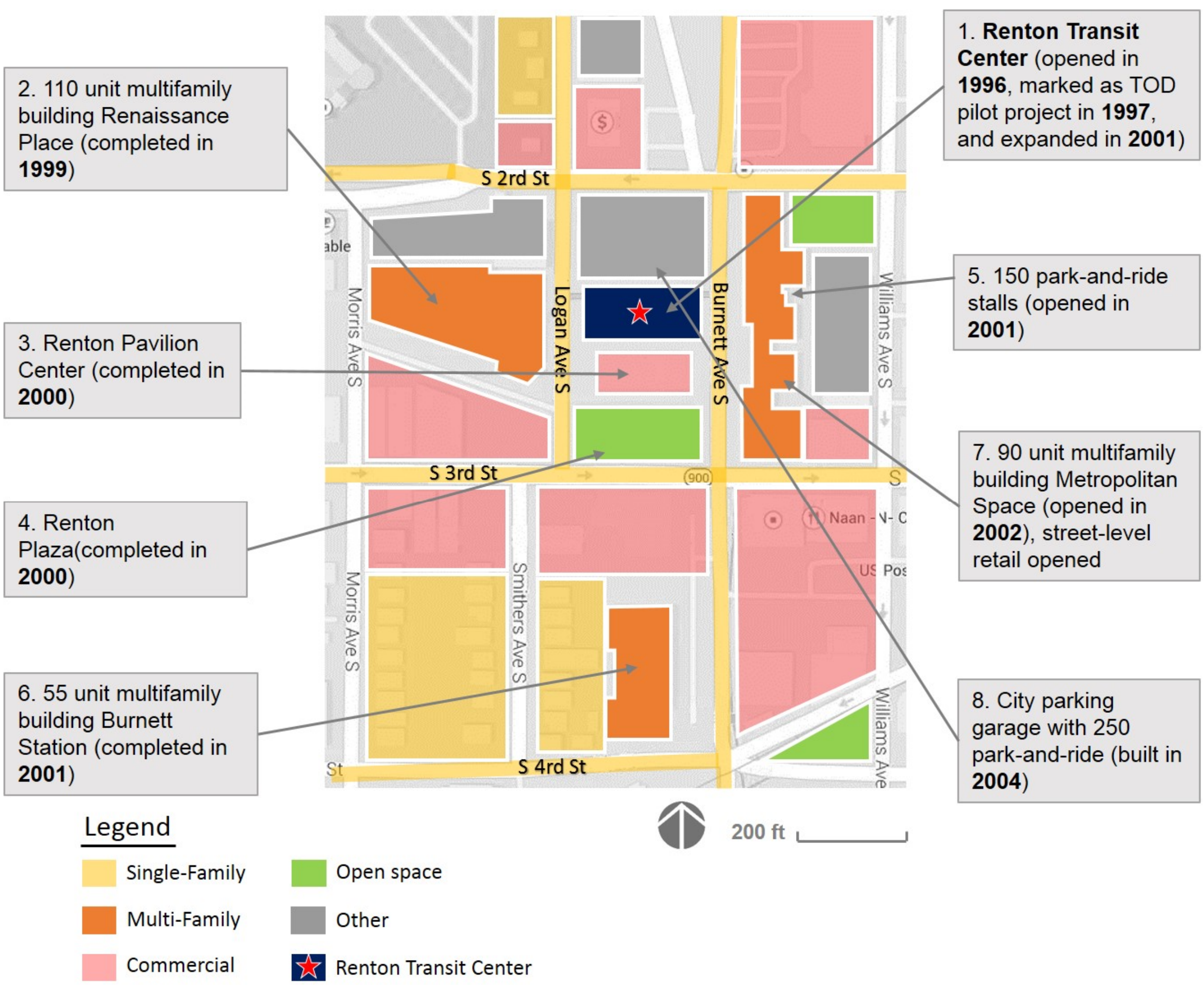

Figure 3 - Transit-oriented development process in Renton Transit Center; ©2015 Google Imagery

In 1995, Renton adopted its first Comprehensive Plan. In that Plan, the area of Renton Transit Center has been zoned to mixed-use designation.

In 1996, the City negotiated with King County Metro over the location of a new transit center. Then, Renton Transit Center opened at 2nd Avenue and Logan Street as an interim transit hub to provide downtown Renton with easy transit access to other part of King County. Meanwhile, the City recruited Don Dally of Dally Properties, a private company, to support mixed-use development around station area.

Shortly after a year, in 1997, King County Metro decided to mark Renton transit center a location for pilot TOD project.

In 1999, Dally Properties completed building the first multifamily building, namely Renaissance Place, a 110-unit apartment complex, near the Transit Center area. In the same year, King County and Dally made an agreement of joint development of TOD project.

In 2000, Renton Piazza, a green plaza adjacent to the transit center was completed. Around the same time, another project used for banquet venue, Renton Pavilion Center, was then completed near transit center.

In 2001, King County Metro Transit renovated and expanded the Renton Transit Center to include additional parking, a plaza, new bus layover, loading areas and street intersection improvements. The work also includes new paving, shelters, landscaping and other passenger and pedestrian improvement as joint-development projects of King County Metro Transit and City of Renton, costs for approximately $4.4 million (King County Department of Transportation, 2010). In the same year, Dally Property built the second multifamily project – Burnett Station, a 55-unit apartment complex near the transit center.

Meanwhile, Dally Homes decided to develop Metropolitan Place Apartment, which has 90 apartments above a two-story garage with 240 parking stalls. King County leases 150 of the parking stalls for park-and-ride uses for 30 years, opened in 2001. King County Metro Transit also made an agreement with Dally Homes, permitted many goals to be met in TOD development while King County created new park-and-ride capacity and Dally created mixed-use affordable housing (King County Department of Transportation, 2010).

In 2002, the newly expanded transit center opened, and 90 apartments of Metropolitan Place opened shortly after. In the same year, 4,000 square feet of street-level retail space built into the northwest corner of Metropolitan Place.

In 2004, city of Renton built a freestanding city parking garage with 250 park-and-ride spaces next to the transit center.

In sum, the transit-oriented developent in Renton Transit Center was started in approximately 1996, with at least a time span of around 9 years (from 1996 to 2004) to complete all TOD components. Therefore, in this analysis, the years before 1996 are treated as before-TOD, the years from 1996 to 2004 are during TOD construction, and the years after 2004 are treated as post-TOD.

CHAPTER 4 DATA AND METHODOLOGY

4.1 METHODOLOGY

Hedonic price method is the most commonly used method to study the marginal implicit housing price as affected by each attribute. In 1966, Lancaster proposed an approach in his paper that the output for a good are a collection of more than one characteristics rather than a homogenous type (Lancaster, 1966). In 1974, Rosen derive implicit attribute prices for multi-attribute goods using Hedonic Price Method. The Hedonic price method assumes that the characteristics which affecting housing price can be decomposed thereby can treat each of them separately in order to estimate prices or elasticity for each of them (Rosen, 1974). Housing prices are affected by their combination of different characteristics. Among these characters, as for this study, TOD is an important part. Besides TOD, there are also other kinds of factors, including locational factors, physical structure factors, and social-economic factors that affect housing price. Therefore, using Hedonic method can disentangle the effect of different attributes of housing price in order to obtain the marginal implicit price of TOD factors.

In this study, rather than using a simple linear functional form, a semi-logarithmic function form is used. Unlike the simple linear functional form measuring the absolute amount of dependent variable change as driven by per unit increase or decrease of independent variables, the semi-logarithmic function estimates the percentage change of dependent variable as according to a unit change of different independent variables. Thus, in order to compare the result of this study with other studies, the "Percentage effects" of semi-logarithmic function is better than a simple linear functional form.

A typical semi-log linear form of Hedonic regression method is used in this study:

$$\ln P = c_0 + \sum \alpha_i A_i + \sum \beta_i B_i + \sum \mu_i U_i + \sum v_i V_i + \sum t_i T_i + \varepsilon$$

Where c_0 is a constant, P is the single family property sales price in 1.5 mile buffer from Renton Transit Center, A_i are the social-economic variables; B_i are the TOD related variables; U_i are other locational related variables; V_i are physical characteristics of the property; T_i are time-series dummy variables capturing different years of transactions.

4.1.1 TWO TIME-SERIES MODELS

In order to answer the research question that to what extent a completed TOD project fulfilled the role of capitalizing residential property value both in time and space, two basic time-series models are built using the typical semi-log form HPA method illustrated before.

Since all the transaction prices were adjusted to 2015 dollar price before analysis using S&P/ Case-Shiller Seattle Home Price Index which only covers a time span between 1990 and 2015, the total time period chosen is from 1990 to 2015 for this time-series analysis which includes 6 years before TOD construction (1990-1995), 9 years during TOD construction (1996-2004), and 11 years after that (2005-2015).

Then, in order to better handle time, time-series dummy variables are used to capturing different years of transactions. To have enough transactions for each time-series dummy variables, two years are combined together as one dummy variable. Therefore, 26 years are divided into 13 periods by 12 time-series dummy variables. The group for properties sold during 2004-2005 is treated as the reference group for these dummy variables since it has the largest sample size.

Table 4 - Time-series observations

Before-TOD		During-TOD		After-TOD	
Year	**Sample size**	**Year**	**Sample size**	**Year**	**Sample size**
1990-1991	42	1996-1997	95	2006-2007	126
1992-1993	92	1998-1999	124	2008-2009	70
1994-1995	93	2000-2001	105	2010-2011	71
		2002-2003	154	2012-2013	92
		2004-2005	240	2014-2015	51

To test whether proximity to TOD would significantly influence property value, two sets of TOD proximity measurements are applied to represent distance to the target transit center. The first set measures the linear distance between the centroid of the observed properties and the centroid of the station using ArcGIS spatial analysis. It is hypothesized that the distance variable is significantly negative, suggesting that transit accessibility has premium effect on surrounding housing value. The second set includes a series of dummy variables representing different ranges of distance between observed properties to the transit center to test the spatial extent of premium effect. It is hypothesized that properties located outside a quarter mile but within a mile to the station have the highest property value because station area properties (properties within a quarter mile distance) are often associated with TOD-related nuisances such as congestion and noise. All transaction properties are divided into four categories: those located within 0.25 mile to the target station; located within 0.25-0.5 mile; within 0.5-1 mile; and within 1-1.5 mile to the target station. Three distance dummy variables are used to categorize them. It is not possible to add all these two kind of variables in a particular regression model because of the collinearity, therefore two models are built separately, and each includes a kind of measurement:

Model 1: $$\ln P = c_1 + \sum o_i O_i + e dis\_TOD + \sum t_i T_i + \varepsilon_1$$

Model 2: $$\ln P = c_2 + \sum o_i O_i + \sum x_i dist\_dummy_i + \sum t_i T_i + \varepsilon_2$$

Where O_i are other variables (including social-economic, locational, physical structure and other TOD related variables) except for the variable of distance to transit center; dis_TOD is the distance between the observed properties and the transit center; $dist\_dummy_i$ are the three dummy variables indicating four distance bands. o_i, e, x_i, and t_i are coefficients, c_1 and c_2 are constants; ε_1 and ε_2 are error terms.

4.1.2 Before-during-after models

Then, in order to answer the question that whether housing price show any difference before and after TOD took into effect, the before-during-after analysis is used to capture the differences. Six models representing before, during, and after the implementation of TOD are then conducted in this study using the basic form of Hedonic model. The first set of three includes distance to TOD as an independent variable, the last set of three measures distance by distance dummy variables.

According to the background of study area TOD development in Chapter 3, the project was started in the year of 1996, and spent for about 9 years (from 1996 to 2004) to finish all the TOD components (transit accessibility, mixed land use and pedestrian-oriented design). Therefore, properties sold before 1996 are used for pre-TOD models, those sold during 1996-2004 are used for during-TOD models, and properties sold on 2005 and after are used for post-TOD models.

A more detailed description of variables and data source are in the following Chapter 4.2.

Model 3:	*Properties sold during 1990-1995 (Pre-TOD) – using distance to TOD*
Model 6:	*Properties sold during 1990-1995 (Pre-TOD) – using distance dummy variables*

Model 4:	*Properties sold during 1996-2004 (Under-construction) – using distance to TOD*
Model 7:	*Properties sold during 1996-2004 (Under-construction) – using distance dummy variables*

Model 5:	*Properties sold during 2004-2015 (Post-TOD) – using distance to TOD*
Model 8:	*Properties sold during 2004-2015 (Post-TOD) – using distance dummy variables*

4.2 DATA

Based on the conceptual model summarized from extensive body of literatures on housing price measured by Hedonic Price Analysis method, variables needed for this study are shown in Table 5. Data for measuring these variables are collected from various sources or calculated in GIS software. The following are the major types of data:

4.2.1 DATA TYPES

TRANSACTION PRICE DATA

The transaction price data comes from real property sales data which contains records for sales, including the sales price, sales date, and principle uses etc. started from 1982 in King County Department of Assessor (KC Assessor). The field name "major" and "minor" are concatenated to create PIN code, which is the key attribute to join to GIS parcel file.

RESIDENTIAL BUILDING RECORD DATA

The residential building record data contains physical structure records such as building grade, square footage, year built, condition etc. for each residential building from KC Assessor. This data file is limited to current status of the building, however the condition of the houses may have changed during the past years. Therefore, an attribute of "renovation year" in this file is used to pick out properties at least have not been renovated after the transaction year.

HOME PRICE INDEX DATA

The home price index data for inflating the previous housing prices into present dollars is from S&P/Case-Shiller Seattle Home Price Index, which measures the average change in value of residential real estate in Seattle started from 1990. Unlike Consumer Price Index from Bureau of Labor Statistics which measures the average change over time in the price paid for the whole major expenditure categories, this Home Price Index only measures the price paid for residential real estate therefore can capture the effect of large economic change (especially the Subprime Crisis in U.S. during 2007-2009) on real estate market.

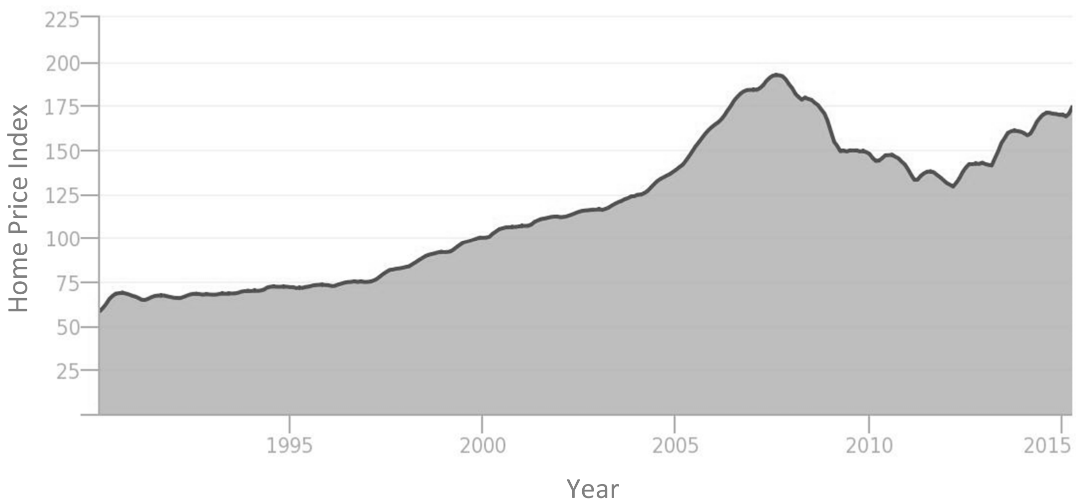

Figure 4 - Home price index in Seattle (Source: S&P/ Case & Shiller Home Price Indices)

PARCEL DATA

The parcel data contains property-related attributes for each parcel of real property, including its area, present use, topography, view, traffic noise, nuisance, etc. The parcel data is also from KS Assessor. It depicts the current condition of the properties but not at the time the properties sold. Thus, using this data may create some inaccuracy.

Various of GIS Shapefile data

The dataset also contains an object-oriented GIS layer of study area parcels from King County GIS Center (KCGIS Center). It provides geometry for spatial analysis and a series of parcel-related information attached to it. An important attribute for this file is the present use of the parcel, which is used for calculating land use mix score, percentage of commercial uses and other land use related variables.

Other GIS data used in this study includes transportation network, lake Washington, river and other bus stops, all are from KCGIS Center.

Social-economic data

The social-economic data are from 2010 Census and American Community Survey (ACS) 5-year Estimate (2009-2013).

4.2.2 Data filtering

ArcGIS is used to identify properties within 1.5 mile distance from Renton Transit Center and sold during 1990 to 2015: First, in order to identify single family properties within 1.5 mile distance to the Transit Center, three criteria are used:

1) The present land use code of the parcel equals to "2", or "6" ("2" means single-family in residential use/residential zone; "6" means single-family in commercial or industry zone). Only around 20 properties are in the land use code of "6". All of these properties are in residential uses according to their photos, tax roll history, and physical characteristics such as number of bathrooms according to King County Parcel Viewer 2.0.

2) Parcels filtered by step 1) should have only 1 living unit to exclude properties not in single-family uses.

3) Because the target of this study is only single-family properties within 1.5 mile distance to the transit center, GIS was used to identify parcels filtered by step 2) are within 1.5 mile buffer from Renton Transit Center.

Using these three criteria, single-family parcels in the study area were identified. Second, real estate transaction data were then joined to those single-family parcels. Using the attribute of "document date", single-family properties sold during 1990 to 2015 were picked out. After that, residential building record data were joined to single-family parcels sold during 1990 to 2015. As physical structure data are limited to current condition, "renovation year" in the residential building record data file was used to identify properties which still maintain physical characteristics at the transaction time. Therefore, properties having "renovation year" larger than "transaction year" were excluded. Other kind of information like social-economic data were also added into the GIS database and matched to each single-family parcels. Land use related data were calculated first using GIS and then also matched to parcels.

Properties in the dataset with missing data or obvious data mistake were then excluded. A total number of 1,355 single-family transactions were identified within the time span from 1990 to 2015 after removing those with sales price equal to "0" meaning mere transferring interest and those having obvious errors made by record (e.g. a normal condition single family house sold for only 149 dollars in recent years; properties with "null" records in most physical characteristics columns).

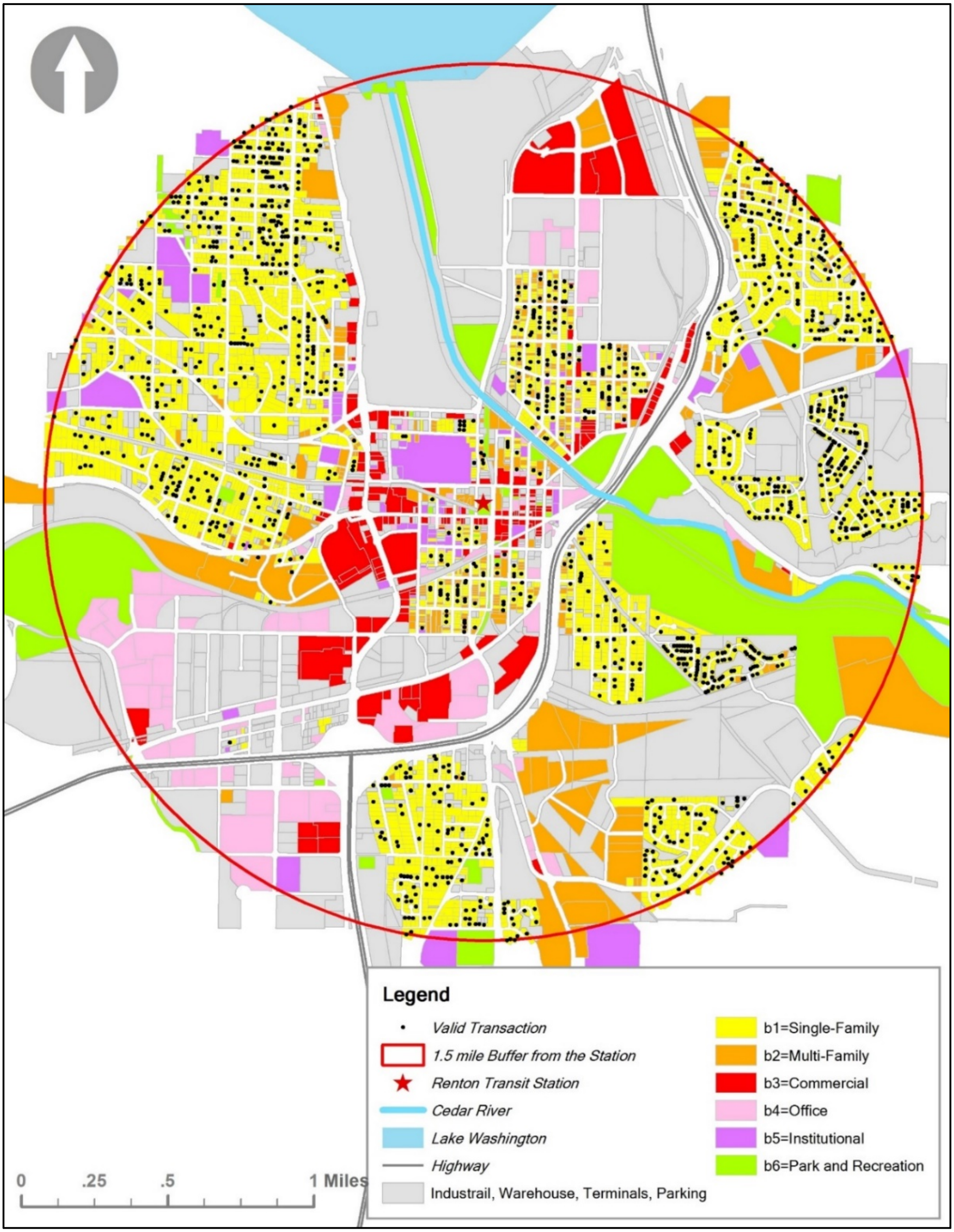

Figure 5 - 1.5 mile buffer of Renton Transit Center

4.2.3 Data by category

Dependent Variable – logarithm of adjusted transaction price

The transaction price data is from KS Assessor. Considering the inflation due to decline in the value of money, transaction price in previous year dollar value are inflated to dollar value in 2015 using annual S&P/Case-Shiller Seattle Home Price Index. The calculation function is as follows:

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

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.

Controlling independent variable – Physical structure variables

The physical structure controlling variables entering in the model are building grade, square footage of finished area above floor, square footage of total basement, number of bedrooms, age of the structure, logarithm of age square, condition of the structure, and number of stories. This series of data are from residential building record from KC Assessor. Since the relation between age of the structure and the housing price is often not linear, and sometimes historic houses are more expensive than moderately new houses, the age square is added into the physical structure variables. In order to reduce severe collinearity in models, age square is transformed into logarithm form first and added together with age into the regression model.

Controlling independent variable – locational characteristics

The locational characteristics include distance to highway, distance to Lake Washington, distance to Cedar River, distance to nearest park, and distance to other bus stops, dummy variables distinguishing whether the property has lake view or not, dummy variables capturing whether the property has detected traffic noise or not, dummy variables capturing whether the property has other kind of nuisance or not. Distance to CBD was originally included in it, but eliminated then subject to severe collinearity of the data.

All the distance data are calculated in ArcGIS using data from KCGIS Center. The highway data is from the dataset of Transportation Network (TNET) in King County GIS Portal, only picking out two types of roads: highways and expressways. The bus stops data (not containing Renton Transit Center) are a merge of Metro bus stops as well as bus stops served by Sound Transit, another transit agency providing regional express service in the study area. The GIS data of Lake Washington, Cedar River and Parks are also from KCGIS Center.

The view of Lake Washington, traffic noise, and other nuisance data are within parcel record data from KS Assessor. Properties are assigned "1" and "0" indicating whether they have these condition or not.

CONTROLLING INDEPENDENT VARIABLE – SOCIAL-ECONOMIC FACTORS

The social-economic variables, including race percentage, median age, and median income, are available from Census and American Community Survey. While race and median age are at block level, median income is at block-group level.

EXPLANATORY INDEPENDENT VARIABLE – TOD-RELATED VARIABLES

The final most important variables are TOD related. Based on previous study on premium effect of TOD from Chapter 2, three kinds of important variables are used to capture TOD premium – proximity to TOD, mixed uses, and pedestrian-oriented design.

To measure proximity to TOD, two sets of models are estimated. The first one uses distance to TOD as an independent variable, the other uses a set of dummy coding distance variables representing different distance bands to the Transit Center. Sometimes the effect of proximity to TOD is not as simple as a linear function because TOD is sometimes associated with negative externalities as Chapter 2 illustrated, therefore the surrounding housing price will impact from how homebuyers trade-off the advantages and disadvantages under different circumstances. Another reason is that, sometimes people are willing to pay similar dollars to two houses, both within a walking distance to the transit station, no matter one of them is a little closer to the station.

Thus, in many previous studies, other than using distance to TOD as an independent variable, another way to compare how proximity to TOD affects property value is using a series of dummy coding variables to test the spatial extent of the price effect of TOD. Various distance bands were tested in previous similar studies (McDonald and Osuji, 1994; Bowes and Ihlanfeldt, 2001; Cervero and Duncan, 2002; Mathur and Ferrell, 2012; Ma, Ye and Titheridge, 2013; Yiming Wang et. Al., 2014; Seo, Golub and Kuby, 2014; Kay, Noland and DiPetrillo, 2014). In this study, all transaction properties are divided into four categories: those located within 0.25 mile of target station; located within 0.25-0.5 mile; within 0.5-1 mile; and within 1-1.5 mile of target station. These four nominal variables are recoded into three dummy variables to capture where each observed property located. Typically, the category with the largest sample size is used as the reference group, thus properties within 1-1.5 mile distance of the transit center with a sample size of 827 is the reference group of this study so that each group will compare with this reference group. Therefore, three variables called dist_dummy1, dist_dummy2, and dist_dummy3 are created, each represents the original variable distance within 0.25 mile, 0.25-0.5 mile, and 0.5-1 mile, respectively.

To measure the presence of mixed land uses within a walkable range around each property, the Land Use Mix Index, the percentage of commercial and the distance to nearest commercial are used. Following Frank et al. (2006), the Land Use Mix Index is an entropy measurement reflecting the evenness of distribution of different land-use types within the region (Frank et al, 2006). The entropy index equation is as follows:

$$Land\ Use\ Mix\ Entropy_n = \frac{-\Sigma(A_{ij}\ln A_{ij})}{\ln N_j}$$

Where A_{ij} is the percent of land use i in boundary j; j is 0.25 mile radius of each observation property n; and N_j is the number of represented land uses in boundary j. Entropy scores varies from 0 (when land use is maximally homogeneous) to 1 (when land use is maximally mixed).

While Frank et al. (2006)'s study use Census tract to define the boundary j, in this study, this boundary is defined by 0.25 mile radius of each observation. Thus, each observation has a specific land use mix value. Similar to Frank's study, this study also measures land use mix for six categories: single-family, multi-family, commercial, office, institutional, park and recreation.

One practical difficulty here in employing land use mix scores is that because of several reasons, such as for taxation purposes, different local jurisdictions categorize land use differently. In King County, for example, there are hundreds of distinct land uses. Some specific land uses are hard to classify into a typical category. Thus, the result of land mix value may incorporate some inaccuracy caused by categorizing process. In this study, hundreds of distinct land uses are classified into 6 categories. Each category and its corresponding land use code from King County parcel file are shown in Appendix C – Land Use Category, Present Land Use Code and Code Definition.

In addition, a typical problem for measuring land use mix through this way is that high land use entropy score sometimes do not imply high level of land use mix because different land use configuration matters a lot. For example, the following two area would achieve the same mixed use scores:

A = ½ Single-family + ½ Multi-family

B = 1/6 Single-family + 1/6 Multi-family + 1/6 Commercial + 1/6 Office + 1/6 Institutional + 1/6 Open Space/Recreation

The area A and B both have the land use mix entropy score of 1.0, but the area B is obviously highly mixed compared with the area A with only residential uses.

Given the potential mistakes caused by the mix use entropy measurement, another variable used to reduce such error is the percentage of commercial uses around a 0.25 mile buffer from the observation calculated in GIS using Parcel data file.

As for the reason why mix use may improve property value is because of the increase in proximity and convenience to daily activities, therefore this study also use distance to the nearest commercial uses as a variable to measure whether close to commercial has advantage on housing value.

To measure a walkable street design, as most previous studies focused on block size, the size of block in which the observation property located is also an independent variable in this study. The block size data is also calculated in ArcGIS software.

EXPLANATORY INDEPENDENT VARIABLE – TIME-SERIES VARIABLES

Then, in Model 1 & Model 2, 12 time dummy variables are used to capture different years of transactions, using properties sold during 2004-2005 as the reference group.

The description of variables and their data source are as follows:

Table 5 - Data description and data source

Variable Name	*Description*	*Source*
Physical Characteristics Variables		
BldgGrade	The score (1-13) representing the building quality from low to high: 1-Cabin; 2-Substandard; 3-Stipulate; 4-Low; 5-Fair; 6-Low Average; 7-Average; 8-Good; 9-Better; 10-Very Good; 11-Excellent; 12-Luxury; 13-Mansion	Residential building record data from KC Assessor
TotalFinis	Square Footage of total finished area above grade of the building	Calculated by adding square footage of each floor above grade using residential building record data from KC Assessor
SqFtTotBas	Square Footage of total basement of the building	Residential Building Record Data from KC Assessor
Bedrooms	Number of Bedrooms of the building	Residential Building Record Data from KC Assessor
Stories	Number of stories of the building	Residential Building Record Data from KC Assessor
Condition	The score (1-5) representing the condition of the building from low to high: 1-Poor; 2-Fair; 3-Average; 4-Good; 5-Very Good	Residential Building Record Data from KC Assessor
Age	Age of the structure	Calculated by the year of 2015 minus the year built using residential Building Record Data from KC Assessor
log_ageSquare	Logarithm of age^2	Calculated the square of the age above
TOD-related Variables		
dis_TOD	Distance between observation property to Renton Transit Center	Calculated in ArcGIS. Each property was geocoded and matched to parcel provided by KCGIS Center
dist_dummy1	1, if property is located within 0.25 mile distance from the Transit Center, 0 otherwise	Calculated in ArcGIS. Each property was geocoded and matched to parcel provided by KCGIS Center
dist_dummy2	1, if property is located within 0.25-0.5 mile distance from the Transit Center, 0 otherwise	Calculated in ArcGIS. Each property was geocoded and matched to parcel provided by KCGIS Center
dist_dummy3	1, if property is located within 0.5-1 mile distance from the Transit Center, 0 otherwise	Calculated in ArcGIS. Each property was geocoded and matched to parcel provided by KCGIS Center
landuse_mi	Land Use Mix Entropy in 0.25 mile radius of each observation using N=6 category	Calculated in ArcGIS using parcel data from KCGIS Center
commercial	Percentage of commercial land uses within 0.25 mile buffer around the observed property	Calculated in ArcGIS using parcel data from KCGIS Center
commercial_dis	Distance from the observation to the nearest commercial land use	Calculated in ArcGIS using parcel data from KCGIS Center
blockSize	Size of the block where the observation located	Calculated in ArcGIS using King County Block GIS data from 2010 Census
Time-series Variables		
Y1990-1991	1, if property sold in 1990-1991, 0 other wise	Real property sales data from KC Assessor
Y1992-1993	1, if property sold in 1992-1993, 0 other wise	Real property sales data from KC Assessor

Y1994-1995	1, if property sold in 1994-1995, 0 other wise	Real property sales data from KC Assessor
Y1996-1997	1, if property sold in 1996-1997, 0 other wise	Real property sales data from KC Assessor
Y1998-1999	1, if property sold in 1998-1999, 0 other wise	Real property sales data from KC Assessor
Y2000-2001	1, if property sold in 2000-2001, 0 other wise	Real property sales data from KC Assessor
Y2002-2003	1, if property sold in 2002-2003, 0 other wise	Real property sales data from KC Assessor
Y2006-2007	1, if property sold in 2006-2007, 0 other wise	Real property sales data from KC Assessor
Y2008-2009	1, if property sold in 2008-2009, 0 other wise	Real property sales data from KC Assessor
Y2010-2011	1, if property sold in 2010-2011, 0 other wise	Real property sales data from KC Assessor
Y2012-2013	1, if property sold in 2012-2013, 0 other wise	Real property sales data from KC Assessor
Y2014-2015	1, if property sold in 2014-2015, 0 other wise	Real property sales data from KC Assessor
Locational Factors		
busStop_dis	Distance in feet between observation to nearest bus stops	Calculated in ArcGIS using bus stops data from KCGIS Center and Sound Transit
highway_dis	Distance in feet between observation to nearest highway	Calculated in ArcGIS using transportation network data from KCGIS Center, only picking out highways and expressways
lake_dis	Distance in feet between observation to Lake Washington	Calculated in ArcGIS using lake data from KCGIS Center
river_dis	Distance in feet between observation to Cedar River	Calculated in ArcGIS using river and stream data from KCGIS Center
park_dis	Distance in feet between observation to nearest park	Calculated in ArcGIS using park data from KCGIS Center
ViewLake	1, if the property has view of Lake Washington, 0 otherwise	Parcel data from KC Assessor
TraNoise	1, if the property has detected traffic noise, 0 otherwise	Parcel data from KC Assessor
OthNuisanc	1, if the property has other nuisance, 0 otherwise	Parcel data from KC Assessor
Social-economic Factors		
p_White	Percentage of white population summarized to the block level	2010 Census, and calculated in ArcGIS
p_Black	Percentage of black or African American population summarized to the block level	2010 Census, and calculated in ArcGIS
p_Asian	Percentage of Asian population summarized to the block level	2010 Census, and calculated in ArcGIS
MedianAge	Median resident age summarized to the block level	2010 Census
Median_inc	Median household income in the past 12 months in 2013 inflation-adjusted summarized to the block-group level	American Community Survey (ACS) 5-year Estimate (2009-2013)
Dependent Variable		
log_InflaPri	Natural logarithm of transaction price of the housing adjusted to 2015 constant dollars	Real property sales data from KC Assessor; Home Price Index from S&P/Case-Shiller Seattle Home Price Index

4.3 Descriptive statistics of the data

The table following are basic statistics for the four categories of independent variables as well as dependent variable used in the time-series models. Maximum, minimum, means and standard deviation are provided for scale or ratio variables, proportions of cases that are equal to “1” are presented for dummy variables.

Table 6 - Descriptive statistics of time-series models

Variable Name	Minimum	Maximum	Mean or Proportion	Std. Deviation
Physical Characteristics				
BldgGrade	4	11	6.85	1.12
TotalFinish (Sqft)	400	8020	1587.51	746.85
SqFtTotBas (Sqft)	0	3050	447.23	546.35
Bedrooms	1	9	3.22	0.94
Stories	1	3	1.39	0.46
Condition	1	5	3.34	0.58
age	1	115	49.85	31.71
log_agesquare	0	9	7.23	1.71
TOD-related Factors				
dis_TOD (Feet)	475.77	7978.26	5546.13	1856.30
dist_dummy1	0	1	0.02	0.15
dist_dummy2	0	1	0.08	0.27
dist_dummy3	0	1	0.29	0.45
Landuse_mi	0.02	1.00	0.51	0.23
commercial (Percentage)	0.00	0.41	0.04	0.07
commer_dis (Feet)	19.90	4129.94	1228.38	737.31
blockSize (Acreage)	0.63	145.54	18.05	31.00
Time-series Dummy Variables				
Y1990_1991	0	1	0.03	0.17
Y1992_1993	0	1	0.07	0.25
Y1994_1995	0	1	0.07	0.25
Y1996_1997	0	1	0.07	0.26
Y1998_1999	0	1	0.09	0.29
Y2000_2001	0	1	0.08	0.27
Y2002_2003	0	1	0.11	0.32
Y2006_2007	0	1	0.09	0.29
Y2008_2009	0	1	0.05	0.22
Y2010_2011	0	1	0.05	0.22

Y2012_2013	0	1	0.07	0.25
Y2014_2015	0	1	0.04	0.19
Locational-related Factors				
highway_dis (Feet)	116.89	8628.15	3605.83	2358.65
lake_dis (Feet)	1034.02	15552.12	7879.69	3563.77
river_dis (Feet)	141.93	8684.99	3377.24	1950.10
park_dis (Feet)	10.19	3464.18	1134.70	742.63
busStop_dis(Feet)	58.19	2884.14	944.78	634.59
ViewLake	0	1	0.08	0.27
TraNoise	0	1	0.12	0.33
OthNuisanc	0	1	0.03	0.16
Social-economic Factors				
p_White	0.00	1.00	0.49	0.21
p_Black	0.00	0.58	0.13	0.10
p_Asian	0.00	0.89	0.26	0.19
MedianAge	0.00	71.30	38.07	6.47
median_inc	0.00	100703.00	63566.22	18717.95
Dependent Variable				
log_InflaPri	9.55	13.83	12.60	0.41
InflaPri	14052	1011814	321733.67	126985.75
Valid N				**1355**

The average inflated value of a single family house within one and a half mile distance to the target transit center is $321,733, with a fair degree of variation. The average distance to the target transit center is 5,546 feet. The number of observations situated within 0.25 mile, 0.25-0.5 mile, 0.5-1 mile, and 1-1.5 mile distance of the target transit center are 33, 106, 389, and 827, respectively. The average land use mix entropy is about 0.5, which means not too homogeneous nor too diverse. Distance to natural amenities and other transportation facilities varies a lot. The mean total finished area above floor is 1,587 square feet with almost an average housing grade and condition. Approximately 50% residents are white, 26% are Asian, and 13% are Black or African American. The median annual income in 2013 is $63,566, about the same level to the median income in Seattle. The median age is 38 years old, similar to the number of 36.1 in Seattle and 37.2 in the U.S.

Next, the following is descriptive statistics by different time periods. Among all the observations, 227 of them were sold between 1990 and 1995, the timespan of before the beginning of Transit-Oriented Development; 602 were sold between 1996 and 2004, the time TOD was on-going; and 526 were sold after 2004, the post-TOD time. For dummy variables, proportions of cases that are equal to "1" are presented. The average inflated value for a single-family house within 1.5 mile distance to the transit center for the time before TOD construction, under construction, and after construction period is $282,806, $335,761, and $322,478, respectively, means that on average properties sold after TOD operation are more expensive than before its operation. Properties sold in before TOD time have smaller total finished area, older age and less stories than properties sold during TOD and after TOD construction time. The average land mix entropy, percentage of commercial land uses, distance to nearest commercial are similar for these three intervals, but properties sold after 1996 typically locates in blocks with larger block size. The average value for most locational-related variables and social-economic variables are about similar for these three different time period.

Table 7 - Descriptive statistics of before-after models

Variable Name	Pre-TOD (1982-1995)		During-TOD (1996-2004)		Post-TOD (2005-2015)	
	Mean or Proportion	**Std. Deviation**	**Mean or Proportion**	**Std. Deviation**	**Mean or Proportion**	**Std. Deviation**
Physical Characteristics						
BldgGrade	6.58	1.09	6.87	1.12	6.95	1.10
TotalFinis (Sqft)	1323.14	648.60	1613.22	740.33	1672.17	769.34
SqFtTotBas (Sqft)	558.70	597.47	397.13	509.18	456.45	557.72
Bedrooms	2.99	0.96	3.20	0.92	3.35	0.94
Stories	1.20	0.36	1.42	0.47	1.42	0.47
Condition	3.36	0.60	3.31	0.54	3.36	0.60
age	62.93	26.40	47.61	32.05	46.78	32.06
log_agesquare	8.06	1.03	7.13	1.67	6.99	1.87
TOD-related Factors						
dis_TOD (Feet)	5510.87	1942.46	5534.73	1890.03	5574.41	1781.00
dist_dummy1	0.02	0.15	0.03	0.18	0.02	0.12
dist_dummy2	0.07	0.26	0.09	0.28	0.07	0.26
dist_dummy3	0.31	0.46	0.25	0.43	0.32	0.47
Landuse_mi	0.55	0.21	0.51	0.23	0.50	0.23
commercial (%)	0.04	0.07	0.04	0.07	0.04	0.08
commer_dis (Feet)	1169.79	735.59	1245.85	727.94	1233.67	748.77
blockSize (Acreage)	14.35	21.34	19.36	33.06	18.14	32.00
Locational-related Factors						
highway_dis (Feet)	3638.86	2428.60	3523.04	2353.66	3686.33	2335.03
lake_dis (Feet)	7581.54	3623.63	7999.87	3602.69	7870.83	3491.31
river_dis (Feet)	3693.43	1929.49	3292.38	1981.16	3337.91	1912.85
park_dis (Feet)	1087.06	746.99	1121.49	741.18	1170.39	742.17

busStop_dis (Feet)	864.78	562.57	974.63	648.48	945.15	645.87
ViewLake	0.11	0.31	0.06	0.24	0.08	0.27
TraNoise	0.15	0.36	0.10	0.31	0.13	0.34
OthNuisanc	0.03	0.17	0.03	0.16	0.02	0.15
Social-economic Factors						
p_White	0.56	0.20	0.48	0.22	0.47	0.21
p_Black	0.12	0.10	0.13	0.09	0.13	0.10
p_Asian	0.19	0.15	0.27	0.20	0.28	0.20
MedianAge	39.77	6.95	37.75	6.42	37.69	6.19
median_inc	61449.02	16627.14	64544.79	18753.04	63359.96	19465.97
Dependent Variable						
log_InflaPri	12.46	0.46	12.65	0.40	12.62	0.38
InflaPri	282806.48	119153.18	335761.30	135023.32	322478.62	117151.88
Valid N		227		602		526

CHAPTER 5 MODEL RESULTS

5.1 RESULTS OF TIME-SERIES MODELS

Multiple linear regression analysis are conducted using SPSS Statistic 22. The results of Model 1 and Model 2 are displayed below. F-tests show that both Model 1 and Model 2 are significant at 99%. The adjusted R-squares equal to 0.47 which means that about 47% percent of deviation from the mean in the dependent variable could be explained by the models. The histograms and the P-P plots of the residuals suggested that the residuals are distributed normally. The results of Durbin-Watson test is 1.900 and 1.904 respectively which are nearly close to 2 means that there is very small chance of residual autocorrelation thus the independent variables are nearly independent. Multicollinearity diagnostic shows that the VIF of all the independent variables are below 10 except for the age and logarithm of age square, which means no serious multicollinearity high enough to bias the estimates. The absolute value of Pearson correlation scores significantly higher than 0.7 are exist between the total finished area and stories, total finished area and logarithm of age square, as well as the percentage of White and percentage of Asian. Table 8 shows the standardized coefficients, significance levels, adjusted R squares, ANOVA diagnostics, and DW diagnostics for Model 1 and Model 2 (See Appendix for other regression details).

Table 8 - Regression results for Model 1 & Model 2

Variable Name	Model 1 - Using Distance			Model 2 - Using Dummy Variables		
	Unstandardized Coefficients - B	Standardized Coefficients - Beta	Significance	Unstandardized Coefficients - B	Standardized Coefficients - Beta	Significance
Physical structure variables						
BldgGrade	0.093	0.253	0.000	0.090	0.246	0.000
TotalFinis	0.000	0.174	0.000	0.000	0.169	0.000
SqFtTotBas	0.000	0.116	0.000	0.000	0.115	0.000
Bedrooms	0.039	0.089	0.001	0.038	0.088	0.001
Stories	0.057	0.064	0.091	0.059	0.066	0.080
Condition	0.042	0.059	0.013	0.040	0.057	0.015
age	-0.005	-0.385	0.000	-0.005	-0.399	0.000
log_agesquare	0.087	0.363	0.000	0.089	0.371	0.000
TOD-related variables						
dis_TOD	-8.87E-06	-0.040	0.300	-	-	-
dist_dummy1	-	-	-	0.208	0.079	0.004

dist_dummy2	-	-	-	0.037	0.024	0.432
dist_dummy3	-	-	-	0.049	0.055	0.055
Landuse_mi	-0.054	-0.030	0.310	-0.057	-0.031	0.285
commercial	-0.351	-0.062	0.058	-0.470	-0.082	0.012
commer_dis	8.84E-06	0.016	0.647	0.000	0.021	0.552
blockSize	0.001	0.054	0.012	0.001	0.052	0.016
Time-series variables						
1990_1991	-0.090	-0.038	0.081	-0.091	-0.039	0.076
1992_1993	-0.120	-0.074	0.002	-0.118	-0.072	0.002
1994_1995	-0.144	-0.089	0.000	-0.145	-0.090	0.000
1996_1997	-0.143	-0.089	0.000	-0.143	-0.089	0.000
1998_1999	-0.028	-0.020	0.412	-0.029	-0.020	0.396
2000_2001	-0.041	-0.027	0.256	-0.042	-0.028	0.240
2002_2003	0.033	0.026	0.296	0.033	0.026	0.294
2006_2007	0.000	0.000	0.991	0.000	0.000	0.997
2008_2009	-0.024	-0.013	0.563	-0.022	-0.012	0.583
2010_2011	-0.085	-0.046	0.039	-0.083	-0.045	0.044
2012_2013	-0.150	-0.092	0.000	-0.149	-0.092	0.000
2014_2015	-0.176	-0.082	0.000	-0.176	-0.082	0.000
Locational Factors						
highway_di	-8.87E-06	-0.051	0.161	-1.00E-05	-0.058	0.110
lakeWashin	2.71E-06	0.024	0.482	2.67E-06	0.023	0.491
river_dis	-1.05E-05	-0.050	0.120	-8.67E-06	-0.041	0.175
park_dis	-6.68E-06	-0.012	0.638	-1.95E-06	-0.004	0.893
busStop_di	6.21E-05	0.096	0.000	5.99E-05	0.093	0.001
ViewLake	6.30E-02	0.041	0.074	7.30E-02	0.048	0.040
TraNoise	-3.70E-02	-0.030	0.158	-3.20E-02	-0.026	0.225
OthNuisanc	-3.10E-02	-0.012	0.559	-3.40E-02	-0.013	0.525
Social-Economic						
p_White	-0.058	-0.031	0.532	-0.045	-0.023	0.635
p_Black	0.070	0.017	0.553	0.078	0.019	0.506
p_Asian	0.016	0.007	0.867	0.045	0.021	0.626
MedianAge	0.000	0.005	0.854	0.000	0.005	0.853
median_inc	0.000	0.031	0.144	0.000	0.029	0.170
(Constant)	11.133		0.000	11.065		0.000
ANOVA F		32.314	0.000		31.108	0.000
Adjusted R^2		0.468	-		0.471	-
Durbin-Watson		1.900	-		1.904	-
N		1355	-		1355	-

Notes: The following color denotes significance at two-tailed 1, 5, and 10 percent confidence level, respectively.

1%	5%	10%

Since the dependent variable, the inflated property value, is measured in logarithmic term, coefficients are interpreted as the percentage change of Y driven by a unit change of X. For unstandardized variable X, a unit means the original unscaled unit, for example, a unit increase for total finished area is a square footage increase. However, the different scales of units of independent variables make it difficult to assess the relative importance of each variables, therefore standardized coefficients are used which removes the problem of comparing variables with different units by standardizing each variables before doing the regression analysis. For standardized variable X, a unit increase in the standardized variables is equivalent to a standard deviation (SD) increase in the unstandardized variables. Typically, scaled variables with larger standardized coefficients have larger effects on the dependent variable. From the results, scaled variables with significant standardized coefficients larger than 0.1 are building grade, total finish area above the floor, square footage of basement, age and logarithm of age square, indicating that the physical structure of the building is the most important determinant of housing price. However it makes little sense to standardize dummy variables because dummy variables cannot be increased by a standard deviation, therefore regular interpretation for standardized coefficients does not apply. SPSS software uses "B" for unstandardized coefficients, and "Beta" for standardized coefficients. Thus, this chapter will interpret standardized "Beta" coefficients for scaled independent variable, and unstandardized "B" coefficients for dummy variables.

Physical Structure

Most physical structure variables show high significance. The building grade, total finished area, square footage of total basement, and number of bedrooms have the expected positive signs and significant at 99% level of confidence. For instance, the willingness to pay for a SD increment of total finished area (about 746 square feet or 69 square meters) is around 17%, which means that a 100 square feet increase of housing size would increase the housing value for about 2.3%. The willingness to pay for a SD increment of total basement (about 546 square footage) is around 12%, means that a 100 square footage (around 9.3 square meter) increase of basement would increase the property value for about 2.2%. Add a bedroom would probably increase the housing price for about 8.8%, and add a grade of the house (e.g. from low to fair) would rise up the housing price for about 25%. Both age and logarithm of age square are significant at 99% level of confidence. The age of building has an expected negative relationship to the property, e.g., a 30-year-elder house has a 38% to 39% lower housing value than a new house when all else being equal. But this does not mean older houses are always cheaper than newer houses. When looking at logarithm of age square, the coefficient is significantly positive, indicating that the relationship between age and housing price is not linear. Some extremely old house may be more expensive than a current new house. The coefficients of building condition and the building story are significantly positive at 95% and 90% level of confidence respectively in the models, and indicate a 5%-6% rise in the property value with each 0.5-level increase in the building condition, or a 0.5-stories increase for the building.

Locational Factors

Among locational factors, only the distance to bus stops and view of Lake Washington are significant and positively relate with property value at both Model 1 and Model 2. The estimates of the semi-logarithmic function imply that increase the distance between property and bus stop for a standard deviation, that is 634 feet (around 200 meters) is associated with a property value increase of about 9.3 % - 9.6%. Houses with Lake Washington view is worth 6.3% to 7.3% more than those without lake view. Other locational variables are not significant at both Model 1 and Model 2. Thus, hypotheses concerning proximity to highways decreases housing value and proximity to parks increases housing value are not validated in this study.

Social-economic Factors

No significant relationship are found between social-economic factors and housing price. This is likely due, in part, to the insufficient block and block-group sample size for the social-economic data and, in part, to the highly correlation between independent variables of percentage of White and percentage of Asian, with a Pearson Correlation for about 0.8 at two-tailed 0.01 level (See Appendix for correlation diagnosis detail).

TOD-related factors

In terms of the most important TOD-related factors of this study, in Model 2, two of the three distance dummy variables each representing properties located <0.25 mile and 0.5-1 mile to TOD are statistically significant at 99% and 90% intervals, suggesting that significant relationship exists between proximity to TOD and property value as expected. Controlling for the effects of housing structures, social-economics and other locational variables, using properties located within 1-1.5 mile distance from TOD as the controlling group, single family properties located within 1-1.5 mile radius around Renton transit center worth around 20% less than properties within 0.25 mile radius of the transit center, and 5% less than those within 0.5-1 mile of the transit center on average. This means there is a housing price premium of being located near the transit center. The following figure shows the premium effects of proximity to the Renton Transit Center on surrounding property values, the steeper slope within half mile to the station means that there is a real value in living closer to the Transit Center. In addition, the premium effects on property value still exist outside a half mile to the station, but are much smaller than that on station area properties.

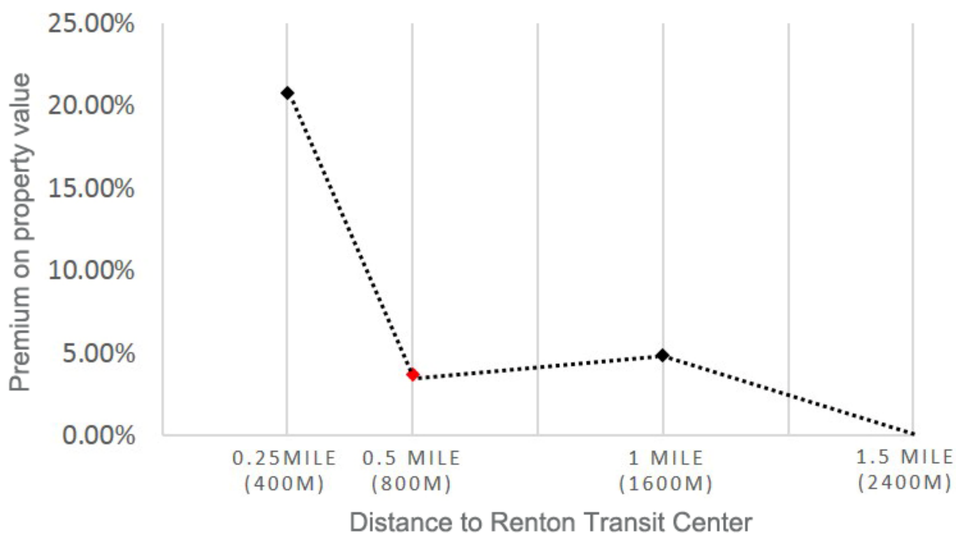

Figure 6 - Unstandardized coefficients of distance dummy variables

Notes: The black markers are coefficients significant below 0.1 level, the red marker is coefficient not significant. The variable representing properties within 1-1.5 mile distance to TOD is treated as the base level.

However, the effect of TOD accessibility measured in distance form in Model 1 is not significant, which may be due to the inclusion of transaction data before the Renton Transit Center operation (before 1996) into the these two time-series regression models.

Model 1 and Model 2 also show a strong yet negative association between the distance to other bus stops (except for the TOD station) and single-family property values. This at least indicates that homebuyers are not willing to pay a premium to a house near regular bus stops, but tend to pay higher price to living close to station with Transit-Oriented Development pattern.

As for the three variables measuring land use diversity, including the land use mix entropy, distance to commercial land uses, and the percentage of commercial land uses within 0.25 mile buffer from the observation, only the last one is statistically significant at 99% interval in Model 2 and 90% in Model 1. The negative coefficients mean that the more commercial uses around the property, the less the property value, when all else being equal. An approximately 7% increase of commercial percentage around 0.25 mile of the property would lead to a 6% or 8% decrease of housing value as Model 1 or Model 2 show. This means living in an environment surrounded by commercial uses tend to have larger negative influences on housing price than the positive effects even if it can provide people with convenient access to their daily shopping activities. In addition, though the coefficients for distance to commercial uses are not significant in both the two models, the positive values may to some extent mean that people do not like living too close to commercial activities. The insignificant coefficients for the mix land use entropy variable suggest that there is no statistically perceptible land use mix premium around one and a half mile distance to properties, when all else being equal. However, this result is questionable, because it is suspected due to the limitation of land use mix index measurement as Chapter 4.2 illustrated.

In terms of the variable measuring pedestrian-oriented design – the block size, the significantly positive coefficients at 90% interval for both Model 1 and Model 2 mean that the larger the block size, the higher the housing value. This results are different to previous studies that house buyers are willing to pay a premium for houses containing smaller blocks or higher levels of street intersections per hectare (Song and Knaap, 2003; Duncan, 2011). Typically, commercial blocks are smaller than residential blocks therefore this result is correspondent with the negative coefficients of commercial percentage.

Time-series dummy variables

Among the 12 time-series dummy variables, 3 of them representing the years from 1990 to 1995 have significantly negative coefficients, indicating that single-family housing values before TOD construction time were approximately 9%-14% cheaper than the two years of 2004 to 2005, about the end of TOD construction period. In the following two years from 1996 to 1997, which is respectively the beginning of Renton Transit Center open and the adoption of TOD, single-family property values within 1.5 mile buffer from TOD largely did not increase. The variables representing properties sold during 2000 to 2003 do not show any statistical significance, suggesting that there is no significant variance between the housing prices during these years and during the two years between 2004 and 2005. In the following year of 2006 and after, the coefficients for the 5 time-series dummy variables show a downward trend though two of them are not significant. Variables representing the year from 2010 to 2015 are significantly negative, indicating that property values were deflated during these years compared with the years from 2004 to 2005. However, this downward trend after 2006 do not necessarily connect to the decay of TOD premium effects. In order to catch a complete understanding of the impact of TOD on single-family property value at different time periods, especially before and after TOD operation, the same Hedonic Pricing Method were conducted for each time periods separately in the following Model 3 to Model 8.

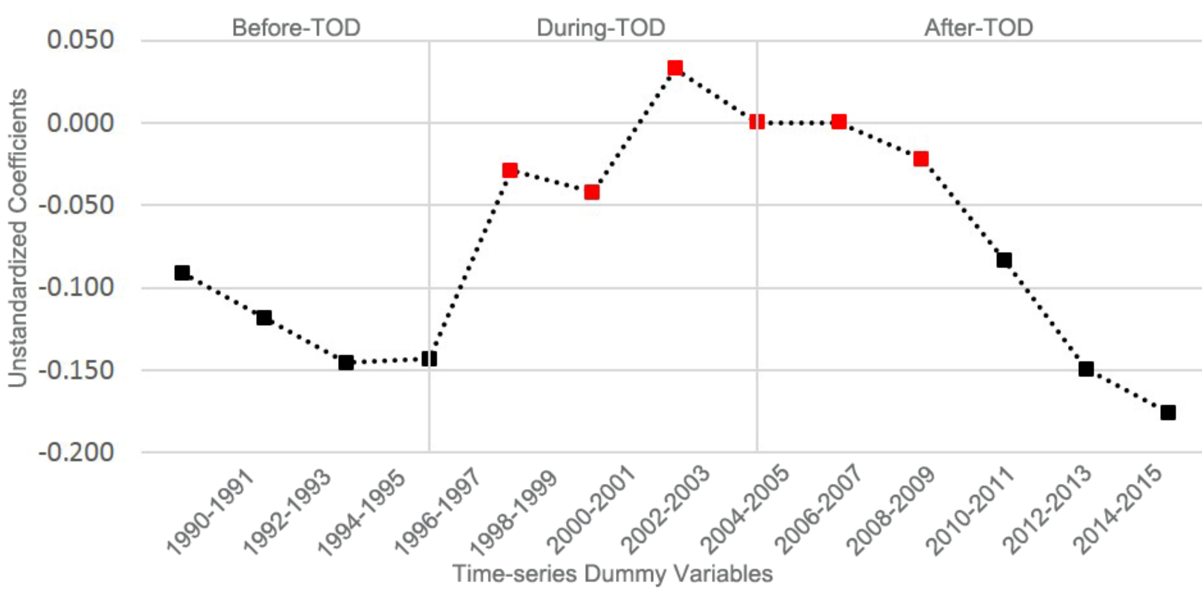

Figure 7 - Unstandardized coefficients of time-series dummy variables

Notes: The black markers are coefficients significant below 0.1 level, the red markers are coefficients not significant. The variable representing properties sold during 2004 to 2005 is treated as the base level.

5.2 Results of before-during-after models

Overall, F-tests show Model 3, 4, and 5 are significant at 99%. The adjusted R-squares of these three models equal to 0.37, 0.51 and 0.47, respectively. The results of histograms and p-p plots of residuals, DW tests and Collinearity diagnostics are acceptable. The absolute value of Pearson correlation scores significantly higher than 0.7 are exist between the total finished area and building grade, total finished area and stories, and between the percentage of White and percentage of Asian in Model 4 and Model 5.

Table 9 - Regression results for Model 3, 4 and 5

Variable Name	Model 3 - Pre TOD			Model 4 - During TOD			Model 5 - Post TOD		
	Unstandardized-B	Standardized-Beta	Sig.	Unstandardized-B	Standardized-Beta	Sig.	Unstandardized-B	Standardized-Beta	Sig.
Physical structure variables									
BldgGrade	0.126	0.298	0.011	0.101	0.283	0.000	0.052	0.152	0.015
TotalFinis	-3.65E-05	-0.051	0.571	0.000	0.254	0.000	0.000	0.306	0.000
SqFtTotBas	0.000	0.168	0.025	0.000	0.154	0.000	0.000	0.119	0.009
Bedrooms	0.038	0.078	0.305	0.025	0.056	0.157	0.044	0.109	0.015
Stories	0.211	0.164	0.052	0.072	0.082	0.136	0.034	0.042	0.522
Condition	0.025	0.032	0.610	0.029	0.039	0.289	0.057	0.091	0.015
age	-0.02	-1.145	0.000	-0.006	-0.478	0.000	-0.003	-0.231	0.071
log_agesquare	0.513	1.149	0.000	0.108	0.444	0.002	0.049	0.242	0.064
TOD-related variables									
dis_TOD	3.61E-05	0.152	0.170	-2.38E-05	-0.112	0.068	-2.74E-05	-0.129	0.030
Landuse_mi	0.316	0.142	0.109	-0.145	-0.083	0.057	-0.034	-0.020	0.672
commercial	-0.627	-0.094	0.374	-0.292	-0.050	0.299	-0.545	-0.109	0.035
commer_dis	-1.83E-05	-0.029	0.770	3.71E-05	0.067	0.190	-1.85E-06	-0.004	0.948
blockSize	0.002	0.081	0.248	0.001	0.046	0.142	0.001	0.074	0.039
Locational factors									
highway_dis	-1.24E-05	-0.066	0.557	-9.16E-06	-0.053	0.324	-8.34E-06	-0.052	0.365
lake_dis	-1.02E-05	-0.080	0.395	1.79E-06	0.016	0.751	1.01E-05	0.094	0.084
river_dis	-1.24E-05	-0.052	0.568	-1.98E-05	-0.097	0.046	1.10E-05	0.056	0.293
park_dis	-8.60E-06	-0.014	0.843	-2.16E-05	-0.040	0.304	1.58E-05	0.031	0.467
busStop_dis	2.92E-05	0.036	0.639	4.38E-05	0.070	0.091	7.95E-05	0.136	0.003

ViewLake	-6.30E-02	-0.042	0.519	7.60E-02	0.045	0.175	1.25E-01	0.091	0.017
TraNoise	-1.41E-01	-0.109	0.069	-6.00E-03	-0.004	0.890	-4.00E-02	-0.036	0.303
OthNuisanc	-2.60E-01	-0.098	0.089	-1.50E-02	-0.006	0.845	1.00E-03	0.000	0.992
Social-economic variables									
p_White	-0.092	-0.041	0.706	0.096	0.051	0.497	-0.206	-0.117	0.174
p_Black	0.127	0.027	0.692	0.136	0.032	0.440	0.080	0.021	0.657
p_Asian	0.167	0.056	0.537	0.149	0.072	0.278	-0.086	-0.045	0.554
MedianAge	0.007	0.109	0.120	-0.005	-0.086	0.025	0.000	0.005	0.900
median_inc	1.33E-06	0.048	0.402	-1.32E-07	-0.006	0.842	1.38E-06	0.071	0.037

(Constant)	7.754		0.000	11.25		0.000	11.372		0.000
ANOVA F		5.989	0.000		24.609	0.000		18.721	0.000
Adjusted R^2		0.365			0.505			0.467	
Durbin-Watson		1.949			1.616			2.011	
N		227			602			526	

Notes: The following color denotes significance at two-tailed 1, 5, and 10 percent confidence level, respectively.

1%	5%	10%

Most physical structure variables significant in Model 1 and Model 2 are still significant in these three models and the coefficients are with the same expected signs. In both three models, building grade, square footage of total basement, logarithm of age square are positively relate with housing price, while building age is negatively relate with housing price. The total finished area is positively relate with housing price in Model 4 and Model 5. Number of bedrooms, stories and building condition are only significant in one of these models.

In terms of other controlling variables, coefficients of distance to others bus stops are significantly negative in both Model 4 and Model 5 yet not significant in Model 3 which may due to the fact that most transit services were not available during that time. The significantly negative coefficient of distance to river in Model 4 means that the closer to the river, the higher the housing price, however which is not found in Model 3 and Model 5. The view of lake dummy variable is significant in Model 5, indicating that during post-TOD time, houses with lake views are sold higher prices than those without lake views. However, the significantly positive coefficients for the distance to lake are inexplicable. The dummy variables representing traffic noise and other nuisance are significant in Model 3 and are negatively associated with housing price, as expected. Houses with detected traffic noise and other kinds of nuisance sold around 14% and 26% lower price, respectively, than otherwise comparable houses but without these nuisance. However, these effects have not found to be significant in during and post TOD periods.

Homeowner median income is positively relate to single-family property value and the coefficients are significant at 95% confidence level in Model 5. This somewhat validates the hypothesis that people tend to live in a place where residents have the similar income as theirs.

Finally, we turn to TOD-related factors, the focus of this study. None of them are tested to be significant in pre-TOD time. The hypothesis concerning proximity to transit center increases property value is to some extent validated in this before-during-after analysis. In Model 3, the coefficient of the variable measuring distance to TOD is insignificant and positive, indicating there is no accessibility premium during pre-TOD time. However, the accessibility effect, on the contrary, is significant after TOD took into effect and still maintains in post-TOD time. In TOD-construction time, increase in the accessibility to the Transit Center by one standard deviation distance (1890 feet, or about 0.36 mile) is associated with an 11% increase of the housing price. In post-TOD time, the premium effect of transit accessibility seems even stronger, because increase in the accessibility by one standard deviation distance (1781 feet, or about 0.33 mile) is linked to a 13% increase of the housing price.

The variables representing land use mix entropy and commercial percentage are significantly negative in TOD construction time and post-TOD time respectively, which to some extent indicating that people still do not like living surrounded by too much non-residential commercial activities. The positive coefficients of block size in Model 5 indicate that houses tend to have lower values if locate in smaller blocks, which corresponds to the results of commercial percentage since commercial district typically has smaller block size. Curiously, these negative effects of commercial tend to be significant after TOD operation, which may suggest that TOD construction or commercial activities create some negative influences on surrounding housing price as previous studies found. But this is also suspected due to the limitation of using the current land use data for measuring previous year condition.

The following are the regression results for Model 6 to Model 8 using three distance dummy variables to measure transit accessibility. The overall statistical results are similar to Model 3 to Model 5.

Table 10 - Regression results for Model 6, 7 and 8

Variable Name	Model 6 - Pre TOD	Model 7 - During TOD	Model 8 - Post TOD

	Unstandardized-B	Standardized-Beta	Sig.	Unstandardized-B	Standardized-Beta	Sig.	Unstandardized-B	Standardized-Beta	Sig.
Physical structure variables									
BldgGrade	0.128	0.302	0.009	0.101	0.283	0.000	0.049	0.144	0.021
TotalFinis	-4.03E-05	-0.057	0.527	0.000	0.244	0.000	0.000	0.300	0.000
SqFtTotBas	0.000	0.165	0.024	0.000	0.153	0.000	0.000	0.119	0.008
Bedrooms	0.037	0.076	0.310	0.025	0.056	0.153	0.043	0.107	0.017
Stories	0.203	0.158	0.059	0.073	0.084	0.130	0.044	0.055	0.403
Condition	0.023	0.030	0.627	0.026	0.034	0.347	0.056	0.090	0.016
age	-0.020	-1.161	0.000	-0.006	-0.508	0.000	-0.003	-0.221	0.082
log_agesquare	0.515	1.152	0.000	0.112	0.461	0.001	0.049	0.241	0.064
TOD-related variables									
dist_dummy1	0.349	0.111	0.130	0.232	0.103	0.019	0.260	0.084	0.029
dist_dummy2	-0.141	-0.081	0.343	0.134	0.093	0.050	0.088	0.060	0.214
dist_dummy3	-9.50E-02	-0.096	0.210	0.063	0.067	0.110	1.05E-01	0.129	0.005
Landuse_mi	0.354	0.159	0.068	-0.152	-0.087	0.045	-0.045	-0.027	0.575
commercial	-1.316	-0.196	0.066	-0.410	-0.071	0.157	-0.583	-0.117	0.023
commer_dis	-2.17E-05	-0.035	0.731	3.28E-05	0.059	0.240	1.46E-06	0.003	0.959
blockSize	0.002	0.079	0.257	0.001	0.043	0.170	0.001	0.065	0.068
Locational factors									
highway_dis	-1.35E-05	-0.071	0.509	-1.14E-05	-0.066	0.219	-1.06E-05	-0.066	0.245
lake_dis	-1.21E-05	-0.095	0.306	1.22E-06	0.011	0.831	1.06E-05	0.098	0.071
river_dis	-5.76E-06	-0.024	0.768	-1.96E-05	-0.096	0.035	9.10E-06	0.046	0.364
park_dis	1.28E-05	0.021	0.773	-1.68E-05	-0.031	0.431	1.83E-05	0.036	0.409
busStop_dis	3.12E-05	0.038	0.614	4.80E-05	0.077	0.073	6.92E-05	0.118	0.011
ViewLake	-4.40E-02	-0.029	0.653	7.50E-02	0.045	0.184	1.40E-01	0.102	0.008
TraNoise	-1.25E-01	-0.097	0.104	4.00E-03	0.003	0.918	-3.80E-02	-0.034	0.331
OthNuisanc	-2.41E-01	-0.091	0.116	-1.60E-02	-0.006	0.837	7.00E-03	0.003	0.936
Social-economic variables									
p_White	-0.101	-0.045	0.677	0.104	0.056	0.461	-0.174	-0.099	0.254
p_Black	0.080	0.017	0.800	0.148	0.035	0.401	0.123	0.032	0.500
p_Asian	0.157	0.053	0.561	0.164	0.080	0.234	-0.030	-0.015	0.840
MedianAge	0.007	0.101	0.139	-0.005	-0.083	0.029	0.001	0.013	0.743
median_inc	1.04E-06	0.037	0.511	-1.38E-07	-0.006	0.836	1.25E-06	0.064	0.060
(Constant)	8.03		0.000	11.09		0.000	11.159		0.000
ANOVA F		5.921	0.000		22.982	0.000		17.66	0.000
Adjusted R^2		0.379			0.506			0.47	
Durbin-Watson		1.965			1.615			2.037	
N		227			602			526	

Notes: The following color denotes significance at two-tailed 1, 5, and 10 percent confidence level, respectively.

1%	5%	10%

In terms of the three dummy variables measuring distance to TOD, for Model 6 (the post-TOD period), none of the three distance dummy variables is statistically significant. Only the coefficient for the first one which capturing properties located within 0.25 mile is positive, the other two dummy variables are negatively related with housing price. One plausible hypothesis is that the first distance dummy variable would probably capture the effect of other amenities (e.g. a public theater or something else) before TOD construction in that area on surrounding housing price, or the premium effect of TOD on station area properties was likely happened as early as the decision making stage but had not widely affected property values outside a quarter mile distance. These positive impacts had probably made houses located within 0.25 mile in approximately 34.9% more expensive than houses located within 1-1.5 mile, but the positive influence dissipate quickly outside 0.25 mile range.

However, for Model 7 (TOD construction period), the coefficients for all the three distance dummy variables are positive, and two of them are significant at either 95% or 90% intervals, indicating that a housing price premium took place during the implementation of TOD. Coefficients of the two significant distance dummy variables can be interpreted as houses located within 0.25 mile and 0.25-0.5 mile to TOD were 23.2% and 13.4% higher in price, compared with the houses located 1-1.5 mile distance to TOD. During post-TOD period, the three distance dummy variables are still positive, and there are still two distance dummy variables significant at 95% intervals. Results show that houses within 0.25 mile and 0.5-1 mile of TOD were 26% and 10.5% higher in price compared with houses located 1-1.5 mile distance to TOD during post-TOD construction time.

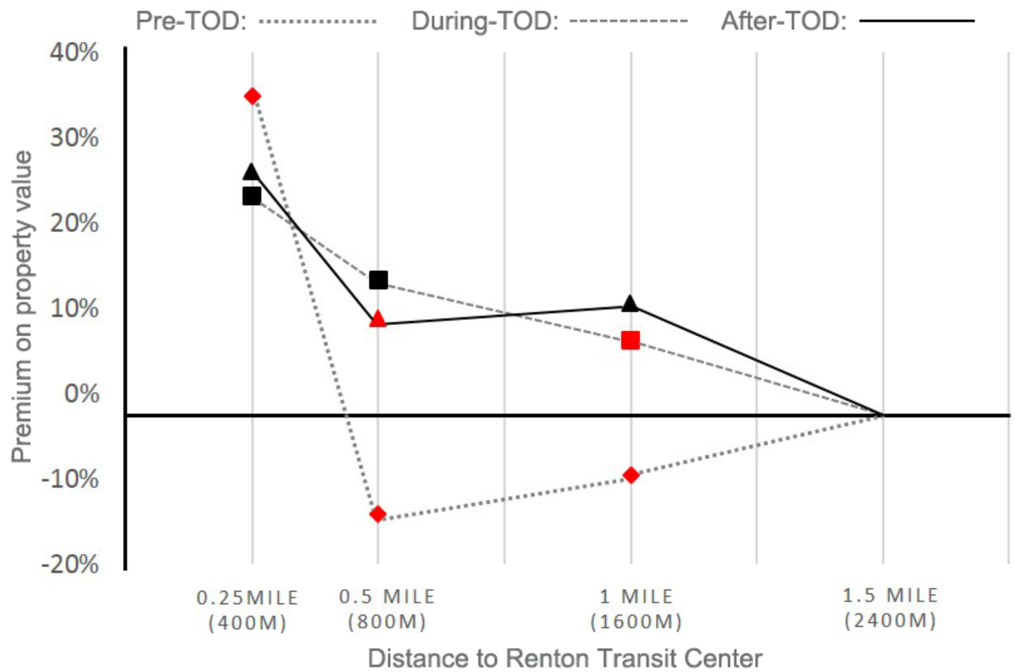

Figure 8 - Unstandardized coefficients of distance dummy variables for three time intervals

Notes: The black markers are coefficients significant below 0.1 level, red markers are coefficients not significant. The dummy variable representing properties located within 1-1.5 mile to TOD is treated as the base level.

Sensitivity Analysis

Sensitivity Analysis is used to figure out how the key input variables impact the output variable under a given circumstance. This method helps to increase the understanding of the relationship between the independent and dependent variables in a model. Since two of the distance dummy variables are significant in Model 7 and Model 8, I use the coefficients of each variable in Model 7 and Model 8 to compute the sale price of four similar houses within four different distance ranges during TOD construction time and post-TOD time, holding scale variables constant at their mean (using transaction data on 1996 and after) and locational dummy variables constant at "0". In general, as the distance to the transit center increases, the housing price decreases, and the identical house sold during TOD construction is a little more expensive than that sold in post-TOD time, holding other variables constant at their mean (i.e. 1640 Sqft of total finished area, 3 bedrooms, average condition, 47 years old, etc.). However, comparing the premium effect of accessibility to TOD during different time period, when other variables constant at their mean, increasing the proximity to TOD from 1-1.5 mile range to 0.25

mile range lifts the house price for about $78,488 in TOD construction time, while an additional $5,000 in post-TOD time.

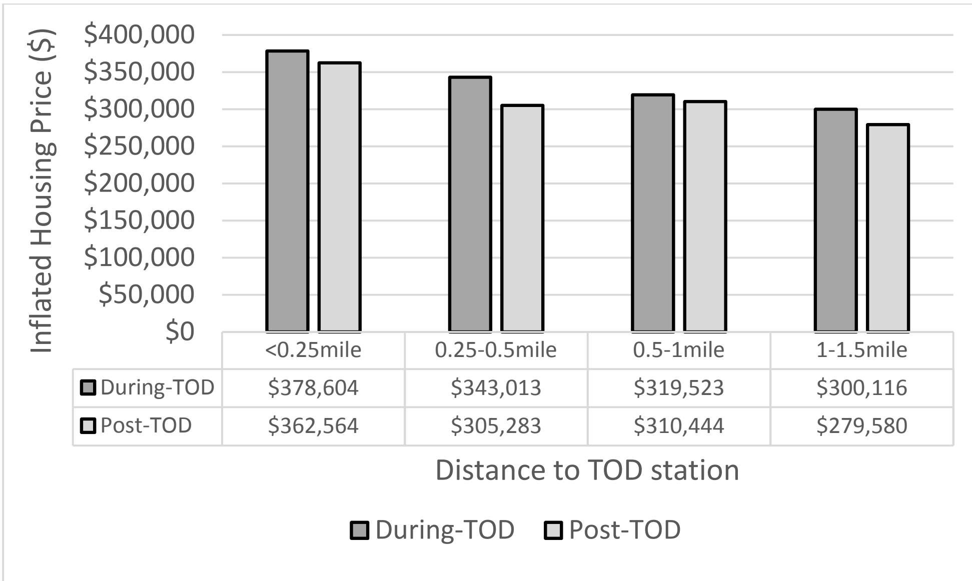

Figure 9 - Variation in inflated housing price at four distance ranges to TOD

Then, z-test is conducted to see whether the coefficients for the variable measuring properties within a quarter mile distance to TOD at each time period are significantly different. This provides more detailed variation of TOD impact on station area properties (properties located within 0.25 mile distance to TOD) for different time periods. For example, we may want to know that whether the 23.2% premium of increasing the proximity to TOD station from 1-1.5 mile range to <0.25 mile range to station in TOD-construction time is significantly smaller than 26% premium of that in post-TOD time; whether the additional $5,000 premium of increasing the proximity to TOD from 1.5 mile range to 0.25 mile range in post-TOD time than that in TOD construction time is statistically believable. The following are the results of z-test for coefficients comparison among models. If the z-value larger than 1.96 or smaller than -1.96, the test is significant at 95% confidence level[1].

[1] The equation to compute z-value: $Z = (Z_{r_1} - Z_{r_2})/\sqrt{1/(n_1-3)+1/(n_2-3)}$; $Z_{r_1} = [\ln(1+r_1) - \ln(1-r_1)]$; $Z_{r_2} = [\ln(1+r_2) - \ln(1-r_2)]$; r_1 and r_2 are coefficients for group 1 and group 2; n_1 and n_2 are sample size for group 1 and group 2.

Table 11 - z-test results

	< 0.25 mile		
Models	M6-M7	M6-M8	M7-M8
z -test	2.426023	1.927971	0.498052

From this table, the coefficient for dist_dummy1 (< 0.25 mile) in Model 6 is significantly higher than that in Model 7, indicating that the insignificant benefit of proximity to where the future TOD located before TOD operation have reduced during the TOD construction time. This suggests that although houses within 0.25 mile distance to TOD station benefit from transit accessibility compared with houses located far away from station, when comparing different time periods before and after TOD implementation, houses within 0.25 mile to station have also suffered from TOD construction nuisance which let their accessibility benefit go down to some extent after TOD operation. However, no significant difference of coefficients found between Model 7 and Model 8, though coefficient for dist_dummy1 in Model 8 is slightly larger than that in Model 7.

CHAPTER 6 CONCLUSION

In this thesis, I use the Hedonic Regression Analysis to measure the impact of Transit-Oriented Development on single-family property value within 1.5 mile radius around Renton Transit Center, a TOD project implemented 18 years ago in King County, WA. A series of regression models were built, Model 1 and 2 are time-series models measuring accessibility to TOD station in different methods (one uses distance, the other uses series of distance dummy variables), and Model 3 to Model 8 takes longitudinal approach by dividing the housing transaction time into three periods: pre-TOD, during TOD construction, and post-TOD intervals. Model 3 to Model 5 uses distance as a measurement of proximity to TOD, while Model 6 to Model 8 uses distance dummy variables. Overall, the results show the dual nature of TOD: proximity to TOD station has been capitalized into property value; however, this benefit has also reduced more or less due to TOD-related nuisance like too much commercial around property, or construction noise for properties located within a quarter mile distance to TOD.

Results of this study show that access to TOD transit station is not statistically significant in Model 1 measuring station accessibility by distance. This may on the one hand due to the inclusion of properties sold before TOD operation into the database, on the other hand because that the relationship between station proximity and housing price is not as simple as a linear function, different price effects happen within different spatial extents and during different time periods. However, when using three dummy variables to represent four ranges of distance to TOD stations, all the dummy variables are positive and two of them are statistically significant, indicating that in general proximity to Renton Transit Center have positively influenced the prices of surrounding homes. In contrast, a notable result is that the coefficients for the variable representing distance to other bus stops are significantly positive, suggesting that the smaller distance to other bus stops, the lower housing price. This may indicate that stations with TOD pattern are at least better than normal transit stops.

When it comes to TOD, most previous studies estimated the property value impacts of transit accessibility, and only very few estimated other TOD components like mixed land use and walkable pedestrian design. This thesis fills this gap by estimating the impact of land use mix entropy, percentage of commercial land use, distance to nearest commercial uses, and block size on property values. Results from the models illustrate that the higher percentage of commercial around 0.25 mile of the property, or the smaller the block size, the lower market value for that property. This means though TOD typically entails mixed land use and walkable pedestrian design which enhances convenience to various kind of retail and commercial services, the negative aspects such as traffic noise and migrants impede the willingness to pay for houses located in an area with too much commercial around it, or with too dense street network systems. Thus, future research should try to find an appropriate mixed development strategy for TOD.

This thesis also uses the real estate transaction data over a 26-year period, the first two models take time-series approaches by dividing the 26-year into 13 time periods using 12 time dummy variables. Controlling for the effect of other variables including large economic background, results found that properties sold before TOD operation and the two years of the beginning of TOD (1996-1997) are significantly less expensive than properties sold during 2004-2005, in TOD operation time. Properties sole after 2009 are also less expensive than those sold during 2004-2005. Moreover, no significant difference found between the properties sold during 1998 to 2009 and properties sold in 2004-2005.

Results from longitudinal models reveal that before the implementation of TOD, proximity to TOD station has insignificant positive effects for houses within 0.25 miles. This positive influences on property value are probably due to presence of other amenities around the station before TOD implementation or the premium effect of TOD began as early as the decision making stage. However, all the distance to TOD dummy variables are positive and gradually decreasing in TOD construction time and in post-TOD time, and two of them are significant in each of these time periods, suggesting that accessibility to transit station has raised surrounding housing value after the station went into operation. Yet when comparing the coefficients of the variable representing station area properties (properties located within 0.25 mile distance to TOD) during different time periods, results show that the premium effect of accessibility to TOD on station area (i.e. within 0.25 mile) property has actually reduced after TOD operation than before-TOD time.

While this study seeks to measure the real impact of TOD on single-family property value using time-series models and before-during-after models controlling for the influences of other property value factors, there are some limitations:

First, this study does not fully control the effects of other non-TOD variables. It is possible that social-economic data and locational data (including some TOD-related variables like distance to commercial, mixed land use and block size) used in this study are inaccurate because they are limited to current situations but not the situation at the transaction time. All the social-economic data are from Census

2010 even if some of the properties were sold 10 years ago. As for locational variables, it is extremely difficult to obtain GIS spatial data in previous years. All of these would affect the result of this study; however, the most important key variable – distance to TOD would not be affected.

Second, this study focuses on a case of bus transit center with TOD pattern in Seattle Metropolitan Area. Since housing price effect of TOD is likely to vary considerably by different transit types and settings as illustrated in Chapter 2, this study may be less convincing for premium effect of other kind of transit types in other part of region.

This study measures the impact of Transit-Oriented Development (TOD) on single family property value using a real-world TOD project in Seattle Metropolitan Area. Major results of this study corroborate the mainstream view that TOD have premium effects on surrounding property value, but this benefit can also reduce due to TOD-related nuisance. In this case, local government under fiscal stress can generate additional revenue source through innovative transit-oriented development projects and programs if it finds an appropriate strategy for mixed land use development near the station.

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APPENDIX

Appendix-A Literatures on the impact of social-economic factors on residential property Value

Reference	Study Area	Methods	Main Variables			Depedent variable	Relevant Finding
			Social and economic	Locational	Physical characteristics		
Martin J. Bailey, 1966	1950 data by census blocks in two Chicago southside areas	Hedonic regression method	race, income	density, university access	floors, rount feet, alley	logarithm of the amount of federal real estate transfer tax paid on the transaction	*There is no indication that blacks pay more for housing than do other people of similar density of occupation.
Victoria Lapham, 1971	650 observations of housing units sold in Dallas in 1960	Identifying differences between white and black in the price paid for common characteristics of housing units identical in every way.	race	minute to downtown, location (address)	square footage, age, number of bathrooms, number of bedrooms, central heat, central air, window	housing sell price	*There is no statistically significant difference in black-white housing costs
King and Mieszkowski, 1973	over 200 rental units in New Haven, Connecticut	Hedonic regression method	race, family size, education of the head of the household	distance from green space,	size, quality	monthly rent inclusive of utilities	*a pure racial discrimination differential in rents of about 7 percent; For black female-headed households the markup relative to white males is 16 percent; for black male-headed households, 7.5 percent.
Charles B. Daniels, 1975	163 census tracts with 59 rental tracts and 78 owner tracts in California	Hedonic regression method	percentage of male employees doing blue collar jobs, dummy varaible denoting census tracts having majority of dwelling units occupied by nonwhites	land elevation, travel time to CBD, dummy variables denoting census tracts with high and above-average concentrations of employment, access to highways	median number of rooms per unit, the percentage of units with basements, the percentage of units with more than one bathroom, quality, sound condition, year built, lot size	Median contract rent; Median estimated sales price	* Black renters may have had relatively stronger preferences for space as compared to quality.
Brian J. L. Berry, 1975	300 real estate transactions involving single-family homes in Chicago	Hedonic regression method	median family income, percentage of black, percentage of latino	linear distance to CBD	square footage, age, lot area, air conditioning, basement, no.of baths, garage	market value of the structure and value of the lot	*controlling other characteristics, price levels and rates of price increase were lower in black than in white neighborhoods

Reference	Study Area	Methods	Main Variables			Depedent variable	Relevant Finding
			Social and economic	Locational	Physical characteristics		
Robert Schafer, 1977	Boston urbanized area, restricted to rental market	Hedonic regression method	average neighborhood income, proportion black, black household head, proportion of puerto Rican	located in central city	room, heat, units, central air conditioning, basement, bathrooms, year built, complete pumbing, length of residency	logarithm of gross monthly rent, including utilities	* Housing prices are substantially higher in the ghetto and transition areas than in white areas, and that within the same area blacks must pay more than whites for equivalent housing.
Daniel N. Chambers, 1991	24 residence zones in Chicago, using 1975 Annual Housing Survey	Hedonic regression method	dummy variable that equals differentiate race of household head, percentage of housing units in the zone occupied by black-headed household	street noise, heavy street traffic, crime, street lighting, odors schools, public transportation etc. distance from CBD	room, bedroom, housing type, heaterm air-condition, person per room, age in structure etc.	rent price	*The previously measured SMSA-wide housing price discount to blacks is seriously overstated; *Household price differentials vary both across different racial submarkets and between 1975 and 1979; *Racially changing neighborhoods near predominantly black areas receive substantial price discounts relative to racially stable neighborhoods.
Li and Brown, 1980	southeast sector of the Boston metropolitan area	Hedonic regression method	neighborhood media income, residential density (number of housing units per square mile), percentage of high	distance to ocean, distance to river, distance to expressway, distance to conservation, distance to recreation area, distance to school	number of rooms, number of bathrooms, fireplaces, grage spaces, basement, age	781 sales of single-family houses	*Median income of census tract is significant at the .05 level.
Follain and Malpezzi, 1981	39 large Standard Metropolitan Statistical Areas (SMSAs)	Hedonic regression method	race, crowding, central city dummy variable, street crime	airplan noise, inadequate schools, inadequate shopping, street traffic	bath, age, rooms, bedroooms, house rating, central heat, elevator, number units etc.	monthly gross rent	*in most markets blacks pay less for comparable housing than non-blacks. The average discount for blacks is about 15 per cent for owners and 6 per cent for renters.
Mankiw and Weil, 1989	74,565 households in U.S, using 1970 Census	demand equation	different age class, housing demand	none	none	Demand for housing, housing price	*changes in the age composition of the population affect demand of housing, and there is a strong and highly significant relation between housing demand and age.
Green and Hendershott, 1993	U.S using 1980 Census	hedonic function and demand equation	different age class, eduction, income, marital status, race, gender	none	number of room, age of house, bathrooms, central air, gas heat, etc	real house price	*only a modest impact of demographic factors on housing price
Herbert and Belsky, 2008	U.S. Metropolitan	discriptive analysis	race, income	bars on windows, trash or junk on street, commercial or industrial property, central city, suburb	housing structure type, size, quality, median square feet	none	*Low-income and minority home buyers is reflected in a higher propensity to live near commercial or industrial properties than moderate and high income homebuyers; large percentage of low-income home buyers purchase manufactured housing.

Appendix-B Literatures on the impact of locational factors on residential property Value

Reference	Study Area	Methods	Main Variables			Depedent variable	Relevant Finding
			Social - Economic	Locational Factors	Physical Structure		
Soren and Sarah, 2006	Minneapolis –St. Paul metropolitan area	hedonic regression method	income, crime, under 18, over 65	distance to park, distance to golf, distance to cemetery, distance to lake, distance to river, size of park, size of golf, size of lake, density, CBD	lot size, bathrooms, age, fireplace	sale price	Proximity to open space is higher in neighborhoods that are dense, near the central business district, high-income, high-crime, or home to many children.
Troy and Grove, 2008	Baltimore, MD	hedonic regression method	median household income, high school graduation, median age, robbery, rape rate	distance to downtown, distance to interstate, distance to nearest park	square footage of structure, parcel area, bath, structure year, quality	housing transaction sale price	When crime rate is relatively low, parks have a positive impact on property. As crime rates climb above a threshold, the direction of the relationship switches and parks negatively influence home values.
Jacqueline Geoghegan, 2001	Howard County, Maryland	hedonic regression method	population density, education level, median income	distance to washington DC, distance to Baltimore, distance to nearest town, percentage of land in 1600m buffer in developable open space and that in permanent open space	lot size, year built, square footage, number of stories quality	inflated transaction price	Coefficient on permanent open space being over three times the magnitude as the estimated coefficient on developable open space
Troy Bowman et. Al, 2009	Cedar Rapids, Iowa, United States	Hedonic price models	median income, test score	distance to closest public park, distance to closest large shopping center, distance to downtown, proximity to railroad track, open space insubdivision area, proximity to forest, proximity to stream	house size, bedrooms, basement, story, lot size, age	inflated transaction price	Well-integrated conservation features (e.g. protected stream corridors) within subdivisions have a positive effect on home prices.
Bolitzer and Netusil, 2000	portland, Oregon	Hedonic price models	none	distance to open space, open space type (public park, private park, cemetery, golf course)	bathroom, fireplace, lot acreage, square feet	home sales price from 1990 to 2000	Distance from a home to an open space and the type of open space can have a statistically significant effect on a home's sale price.

Reference	Study Area	Methods	Main Variables			Depedent variable	Relevant Finding
			Social - Economic	Locational Factors	Physical Structure		
Netusil, 2005	portland, Oregon	Hedonic price models		zoning code, slope, wetland, tree canopy, distance to open space	lot square footage, house square footage, bathrooms, fireplaces, age	real estate sale price between 1999 abd 2001	"Urban parks" where more than 50% of the park is manicured or landscaped are valued negatively between 200 ft and ½ mile of a property while the "natural parks" where more than 50% is preserved in "natural" vegetation, had no effect of property value.
Seong-Hoon et al., 2006	Knox County, Tennessee	Hedonic price models	per capita income, unemployment rate	travel time to work, housing density, high school district, distance to water boday, distance to greenway, park size	finished area, lot size, age bedroom, garage, fireplace, condition of structure	housing sale price adjusted to the 2000 housing price index	Natrual amenities like parks and waterbodies are valuable attributes in housing demand and positively impact sale prices.
Lansford and Jones, 1995	Texas	Hedonic price models	none	distance to lake, scenic view, distance to central business district	square feet of living area, condition	housing market price	Waterfront properties command a premium, but marginal price falls rapidly with increasing distance.
Brown and Pollaskowski, 1977	Seattle, WA	Hedonic price models	none	log of distance to waterfront	age of housing, living area, average room size, number of fireplaces, bathrooms, lot size	market sell data for dwelling units from 1969-1974	The value of a property falls with distance from the water.
Geoghegan, Wainger, and Bockstael, 1997	Washington DC	Hedonic price models	% white, % low income， % middle income, % high income	distance to DC, distance to major road, distance to different counties, % open space, residnetial uses, water front	ln lot size, ln age of house, structure	housing transaction data	a 10% increase in the distance to Washington will lead to a 1.7% decrease in the selling price of the house.

Appendix-C Land Use Category, Present Land Use Code, and Code Definition

Land Use Category	Present Land Use Code
Single-Family	2, 6
Multi-Family	3, 4, 5, 11, 16, 17, 18, 20, 25, 49, 56, 57, 193, 272, 341
Commercial	60, 63, 96, 101, 104, 105, 51, 162, 167, 168, 171, 183, 191, 274, 275, 147
Office	106, 118, 126, 202, 273
Institutional	165, 172, 184, 185, 186, 189, 190, 157, 55, 59, 122, 145, 173
Open space/Recreation	58, 140, 143, 149, 150, 153, 156, 166, 188, 279, 333, 337

Code	Definition	Code	Definition	Code	Definition	Code	Definition
0	Unknown	***101***	Retail store	***172***	Governmental Service	***272***	Historic Property (Residence)
2	Single family (residential use / zone)	***104***	Retail (Big box)	***173***	Hospital	***273***	Historic Property (Office)
3	Duplex	***105***	Retail (Discount)	***179***	Mortuary / Cemetary / Crematory	***274***	Historic Property (Retail)
4	Triplex	***106***	Office building	***180***	Parking (Commercial Lot)	***275***	Historic Property (Eat / Drink)
5	4-plex	***118***	Office Park	***182***	Parking (Garage)	***276***	Historic Property (Loft / Warehouse)
6	Single family (C/I Zone)	***122***	Medical or Dental office	***183***	Restaurant / Lounge	***277***	Historic Property (Park / Billboard)
7	Houseboat	***126***	Condominium (Office)	***184***	School (Public)	***278***	Historic Property (Transient Facility)
8	Mobile home	***130***	Farm	***185***	School (Private)	***279***	Historic Property (Recreation / Entertainment)
9	Single family (C/I use)	***137***	Greenhouse / Nursery / Horticulture service	***186***	Service Station	***280***	Historic Property (Misc)
11	Apartment	***138***	Mining / Quarry / Ore processing	***188***	Tavern / Lounge	***299***	Historic Property (Vacant Land)
16	Apartment (Mixed use)	***140***	Bowling Alley	***189***	Post Office / Post Service	***300***	Vacant (Single-family)
17	Apartment (Co-op)	***141***	Campground	***190***	Vet / Animal Control	***301***	Vacant (Multi-family)
18	Apartment (Subsidized)	***142***	Driving Range	***191***	Grocery Store	***309***	Vacant (Commercial)
20	Condominium (Residential)	***143***	Golf Course	***193***	Daycare Center	***316***	Vacant (Industrial)
25	Condominium (Mixed use)	***145***	Health Club	***194***	Mini Lube	***323***	Reforestation (RCW 84.28)
29	Townhouse plat	***146***	Marina	***195***	Warehouse	***324***	Forest Land (Class - RCW 84.33)

(Source: King County GIS Center, http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=parcel_extr.)

Code	Definition	Code	Definition	Code	Definition	Code	Definition
38	Mobile home park	***147***	Movie Theatre	***202***	High Tech / Tech Flex	***325***	Forest Land (Desig-RCW84.33)
48	Condominium (Mobile Home Park)	***149***	Park, Public (Zoo \ Abroretum)	***210***	Industrial Park	***326***	Open Space (Curr Use-RCW84.34)
49	Retirement facility	***150***	Park, Private (Amusement Center)	***216***	Industrial Park	***327***	Open Space(Agric-RCW 84.34)
51	Hotel or motel	***152***	Ski Area	***223***	Industrial (General Purpose)	***328***	Open Space Timber Land / Greenbelt
55	Rehabilitation center	***153***	Skating Rink (Ice / Roller)	***245***	Industrial (Heavy)	***330***	Easement
56	Residence Hall or Dorm	***156***	Sport Facility	***246***	Industrial (Light)	***331***	Reserve / Wilderness Area
57	Group home	***160***	Auditorium / Assembly Building	***247***	Air Terminal and Hangers	***332***	Right of Way / Utility, Road
58	Resort / Lodge / Retreat	***161***	Auto Showroom and Lot	***252***	Mini Warehouse	***333***	River / Creek / Stream
59	Nursing home	***162***	Bank	***261***	Terminal (Rail)	***334***	Tideland, 1st Class
60	Shopping Center (Neighborhood)	***163***	Car Wash	***262***	Terminal (Marine / Commercial Fishery)	***335***	Tideland, 2nd Class
61	Shopping Center (Community)	***165***	Church / Welfare / Religious Services	***263***	Terminal (Grain)	***336***	Transferable Development Rights
62	Shopping Center (Regional)	***166***	Club	***264***	Terminal (Auto / Bus /Other)	***337***	Water Body, Fresh
63	Shopping Center (Major retail)	***167***	Convenience Store without Gas	***266***	Utility, Public	***339***	Shell Structure
64	Shopping Center (Speciality)	***168***	Convenience Store with Gas	***267***	Utility, Private (Radio / TV)	***340***	Bed and Breakfast
96	Retail (Line / Strip)	***171***	Restaurant (Fast Food)	***271***	Terminal (Marine)	***341***	Rooming House
						342	Fraternity / Sorority House

(Source: King County GIS Center, http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=parcel_extr.)

Appendix-D Correlation matrix of data

Correlation matrix code

Variable	Code
log_inflaPri	P
BldgGrade	V_1
TotalFinish (Sqft)	V_2
SqFtTotBas (Sqft)	V_3
Bedrooms	V_4
Stories	V_5
Condition	V_6
age	V_7
log_agesquare	V_8
dis_TOD (Feet)	B_1
Landuse_mi	B_2
commercial (Percentage)	B_3
commer_dis (Feet)	B_4
blockSize (Acreage)	B_5
highway_dis (Feet)	U_1
lake_dis (Feet)	U_2
river_dis (Feet)	U_3
park_dis (Feet)	U_4
busStop_dis(Feet)	U_5
p_WHITE	A_1
p_Black	A_2
p_Asian	A_3
MedianAge	A_4
median_inc	A_5

Correlation Matrix (N=1355)

	P	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	B_1	B_2	B_3	B_4	B_5	U_1	U_2	U_3	U_4	U_5	A_1	A_2	A_3	A_4	A_5
P	1																							
V_1	.587**	1																						
V_2	.559**	.694**	1																					
V_3	.089**	.139**	-.141**	1																				
V_4	.430**	.472**	.591**	.187**	1																			
V_5	.397**	.459**	.738**	-.351**	.417*	1																		
V_6	-.103**	-.228**	-.255**	.128**	-.066*	-.328**	1																	
V_7	-.502**	-.659**	-.645**	.160**	-.386**	-.606**	.321**	1																
V_8	-.471**	-.635**	-.703**	.208**	-.409**	-.712**	.365**	.950**	1															
B_1	.105**	.113**	.069*	-.064*	.127**	.009	.038	-.354**	-.245**	1														
B_2	-.146**	-.134**	-.150**	.038	-.173**	-.190**	.143**	.329**	.307**	-.504**	1													
B_3	-.268**	-.295**	-.237**	.074**	-.182**	-.128**	.060*	.427**	.333**	.646**	.506**	1												
B_4	.297**	.362**	.261**	-.066*	.181**	.134**	-.073**	-.424**	-.329**	.561**	-.352**	-.602**	1											
B_5	.214**	.140**	.231**	-.060*	.134**	.193**	-.065*	-.269**	-.247**	.087**	-.058*	-.155**	.132*	1										
U_1	.049	.173**	.001	.085**	.063*	-.005	-.250**	-.126**	-.074**	.364**	-.408**	-.358**	.334**	-.015	1									
U_2	.212**	.256**	.243**	-.082**	.128**	.162**	.023	-.285**	-.257**	.056*	.143**	.022	.318**	.161**	-.477**	1								
U_3	-.095**	-.028	-.175**	.145**	-.007	-.257**	.170**	.028	.093**	.483**	-.218**	-.108**	.142**	-.121**	-.047	.266**	1							
U_4	-.044	.000	-.014	.025	.045	-.009	-.126**	-.052	-.037	.186**	-.310**	-.104**	-.021	-.022	.399**	-.268**	-.104**	1						
U_5	.380**	.369**	.448**	-.176**	.188**	.364**	-.172**	-.401**	-.388**	.044	-.052	-.193**	.417**	.156**	-.068*	.350**	-.195**	-.277**	1					
A_1	-.199**	-.231**	-.295**	.154**	-.231**	-.357**	.304**	.416**	430**	-.283**	.470**	.218**	-.149**	-.090**	-.397**	.143**	-.029	-.151**	-.132**	1				
A_2	.065*	.149**	.068*	.028	.067*	.068*	-.142**	-.065*	-.072**	.007	-.149**	-.005	-.006	.021	.400**	-.229**	.003	.159**	-.044	-.455**	1			
A_3	.262**	.288**	.364**	-.199**	.270**	.440**	-.301**	-.513**	-.521**	.303**	-.461**	-.289**	.233**	.118**	.293**	-.017	-.070*	.121**	.213**	-.797**	.096**	1		
A_4	.022	.135**	-.057*	.224**	-.030	-.149**	.067*	.133**	.168**	-.111**	.125**	-.003	.024	-.023	.150**	-.076**	-.026	.013	-.075**	.357**	-.072**	-.195**	1	
A_5	.188**	.199**	.186**	-.041	.109**	.146**	-.066*	-.168**	-.152**	.016	-.037	-.076**	.121**	.063*	-.002	.043	-.125**	.024	.219**	-.092**	.052	.118**	-.021	1

Note: Pearson correlation two-tailed tests, ** is significant at the 0.01 level, * is significant at the 0.05 level.

Appendix-E Collinearity statistics VIF

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
BldgGrade	3.660	3.736	4.803	3.698	3.816	4.816	3.860	3.850
TotalFinis	4.448	4.456	2.912	4.574	5.385	2.925	4.580	5.395
SqFtTotBas	1.705	1.700	1.964	1.589	1.998	1.918	1.592	2.002
Bedrooms	1.880	1.882	2.039	1.880	1.953	2.043	1.881	1.970
Stories1	3.592	3.625	2.511	3.706	4.269	2.524	3.749	4.322
Condition	1.416	1.400	1.428	1.634	1.364	1.411	1.621	1.357
age	16.402	16.498	22.357	20.650	16.098	22.897	21.128	15.939
log_agesquare	17.903	17.950	22.826	24.444	16.733	23.112	24.601	16.728
dis_TOD	3.840	-	4.342	4.556	3.460	-	-	-
dis_dummy1	-	1.845	-	-	-	1.956	2.337	1.474
dis_dummy2	-	2.418	-	-	-	2.620	2.732	2.284
dis_dummy3	-	2.075	-	-	-	2.108	2.150	2.130
Landuse_mi	2.199	2.192	2.789	2.288	2.289	2.744	2.275	2.282
commercial	2.690	2.771	3.922	2.846	2.629	4.118	3.021	2.597
commer_dis	3.084	3.058	3.549	3.164	3.109	3.662	3.084	3.098
blockSize	1.179	1.185	1.741	1.176	1.254	1.760	1.187	1.260
1990_1991	1.216	1.216	-	-	-	-	-	-
1992_1993	1.413	1.425	-	-	-	-	-	-
1994_1995	1.412	1.412	-	-	-	-	-	-
1996_1997	1.403	1.403	-	-	-	-	-	-
1998_1999	1.485	1.486	-	-	-	-	-	-
2000_2001	1.398	1.401	-	-	-	-	-	-
2002_2003	1.529	1.527	-	-	-	-	-	-
2006_2007	1.435	1.435	-	-	-	-	-	-
2008_2009	1.251	1.251	-	-	-	-	-	-
2010_2011	1.281	1.288	-	-	-	-	-	-
2012_2013	1.336	1.336	-	-	-	-	-	-
2014_2015	1.214	1.224	-	-	-	-	-	-
highway_di	3.380	3.326	4.427	3.558	3.188	4.188	3.545	3.163
lakeWashin	2.870	2.911	3.165	3.077	2.893	3.132	3.152	2.931
river_dis	2.650	2.374	2.913	2.865	2.780	2.432	2.524	2.557
park_dis	1.687	1.761	1.748	1.803	1.794	1.870	1.862	1.871
busStop_di	1.937	2.054	2.040	2.100	2.029	2.071	2.239	2.134
ViewLake	1.359	1.379	1.529	1.364	1.405	1.547	1.377	1.430
TraNoise	1.147	1.153	1.274	1.121	1.196	1.288	1.133	1.195
OthNuisanc	1.100	1.102	1.163	1.119	1.116	1.196	1.124	1.139
p_WHITE	6.167	6.214	4.153	6.922	7.224	4.208	6.968	7.393
p_Black	2.004	1.997	1.705	2.083	2.242	1.715	2.079	2.274
p_Asian	4.796	4.875	2.892	5.394	5.564	2.971	5.433	5.783
MedianAge	1.624	1.597	1.732	1.781	1.504	1.687	1.762	1.489
median_inc	1.125	1.134	1.156	1.156	1.144	1.172	1.166	1.154