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Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea

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**Abstract:**
More and more cities are turning to Bus Rapid Transit (BRT) as a way of cost-effectively expanding public transit services to help relieve traffic congestion, reduce carbon emissions, and increase mobility options for the poor. Because of the inherent flexibility advantages of rubber-tire buses – e.g., unlike rail systems, the same vehicle that functions as a line-haul carrier can also morph into a neighborhood feeder -- BRT is especially suited for many lower density and non- CBD settings. Some of the most advanced and widely heralded BRT services today are found in Latin America, such as Curitiba and Sao Paulo, Brazil, Bogotá and Cali, Columbia, Santiago, Chile, and Lima, Peru. The success of BRT in these cities stems, to a large degree, from the presence of dedicated lanes, which offer significant speed advantages relative to more traditional mixed-traffic services. One of the few cities outside of Latin America that has joined the ranks of world-class BRT serviceproviders is Seoul, Korea. As in cities like Curitiba and Bogotá, Seoul operates dedicated median-lane BRT services which are supplemented by one of the most extensive networks of curbside BRT lanes anywhere. Seoul began implementing curbside bus lanes in 1986 however because of conflicts with traffic entering the main traffic stream these lanes failed to provide significant speed advantages. It was only after the addition of exclusive median lanes in 2004 that buses began to offer significant travel-time savings and win over former motorists. All else being equal, significant gains in bus speeds should be followed by significant land-use changes, like densification and property value increases, especially in congested mega-cities like Seoul. Land markets can be expected to place a high premium on parcels close to transit corridors that enjoy significant travel-time savings since, after all, such settings have scarcity value – i.e., there is a finite, limited supply of settings with superior transit offerings. This paper probes this hypothesis by studying land-use changes and property-value increases induced by

Seoul's introduction of exclusive, median-lane BRT services. First, the empirical literature on bus transit and land-use impacts is reviewed. This is followed by background discussions on Seoul's transportation conditions and BRT system. Next, we describe our research methodology and supporting data sources. We then present multilevel models that gauge the influences of upgrading BRT services on land-use changes and land values. The paper concludes by reflecting on the policy implications of the key research findings.

# Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea

**Robert Cervero and Chang Deok Kang**

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## 1. Introduction

More and more cities are turning to Bus Rapid Transit (BRT) as a way of cost-effectively expanding public transit services to help relieve traffic congestion, reduce carbon emissions, and increase mobility options for the poor. Because of the inherent flexibility advantages of rubber-tire buses – e.g., unlike rail systems, the same vehicle that functions as a line-haul carrier can also morph into a neighborhood feeder -- BRT is especially suited for many lower density and non-CBD settings.

Some of the most advanced and widely heralded BRT services today are found in Latin America, such as Curitiba and Sao Paulo, Brazil, Bogotá and Cali, Columbia, Santiago, Chile, and Lima, Peru. The success of BRT in these cities stems, to a large degree, from the presence of dedicated lanes, which offer significant speed advantages relative to more traditional mixed-traffic services. One of the few cities outside of Latin America that has joined the ranks of world-class BRT service-providers is Seoul, Korea. As in cities like Curitiba and Bogotá, Seoul operates dedicated median-lane BRT services which are supplemented by one of the most extensive networks of curbside BRT lanes anywhere. Seoul began implementing curbside bus lanes in 1986 however because of conflicts with traffic entering the main traffic stream these lanes failed to provide significant speed advantages. It was only after the addition of exclusive median lanes in 2004 that buses began to offer significant travel-time savings and win over former motorists.

All else being equal, significant gains in bus speeds should be followed by significant land-use changes, like densification and property value increases, especially in congested mega-cities like Seoul. Land markets can be expected to place a high premium on parcels close to transit corridors that enjoy significant travel-time savings since, after all, such settings have scarcity value – i.e., there is a finite, limited supply of settings with superior transit offerings. This paper probes this hypothesis by studying land-use changes and property-value increases induced by Seoul's introduction of exclusive, median-lane BRT services. First, the empirical literature on bus transit and land-use impacts is reviewed. This is followed by background discussions on Seoul's transportation conditions and BRT system. Next, we describe our research methodology and supporting data sources. We then present multilevel models that gauge the influences of upgrading BRT services on land-use changes and land values. The paper concludes by reflecting on the policy implications of the key research findings.

## 2. Literature Review

A large body of literature confirms that urban real-estate responds positively to transportation improvements, mainly in the form of higher property values and, zoning permitting, land-use intensification (Cervero, 1997; Ryan, 1999). Transportation infrastructure increases the supply of developable land and through the competitive bidding process increases the price of land for parcels that enjoy significant gains in accessibility (Du and Mullens, 2006; Dowall and Monkkonen, 2007; Ewing, 2009). The benefits of new transportation investments get capitalized in real estate price in the short-term while over the longer term land use adjustments occur. Thus while land-price impacts can be instantaneous, land-use changes tend to be slower, partly due to institutional lags (e.g., in securing building permits and zoning amendments) (Perez, et al., 2003).

Most transportation capitalization studies to date have focused on highway corridors in the developed world. Given the predominance of automobile travel in countries like the United States, not surprisingly larger value gains have been recorded as a consequence of highways improvements vis-à-vis expanded or enhanced transit services (Cervero, 1997; Ryan, 1999; Bhatta and Drennan, 2003). Studies generally find, however, that the impacts of highways on land-use changes are largely redistributive, shifting growth that might otherwise occur in some settings to newly served highway settings (Cambridge Systematics, et al., 1998; Boarnet, 1998; Boarnet and Haughwout, 2000; Boarnet and Chalermpong, 2001). Research also shows that the farther a highway is from the CBD, in general the smaller the land-price adjustment in aggregate terms (Voith, 1993).

Most studies of transit's impacts on cities and land values have focused on heavy rail systems since such capital-intensive investments have historically conferred the most significant accessibility benefits of any transit improvements. However, empirical research on rail investments and land-price impacts has produced mixed results. Studies of San Francisco's BART found considerable variation in land-price impacts, with downtown San Francisco commercial properties reaping huge gains and many suburban residential settings experiencing no discernible impacts (Cervero and Landis, 1997). Research on Miami's Metrorail recorded no significant land-price effects owing to low ridership and flat real-estate markets in many areas that were served (Gatzlaff and Smith, 1993). A study of Chicago's Midway Line showed that the opening of new rail services increased housing prices, with rates of land-value appreciation varying over time (McMillen and McDonald, 2004).

Conventional wisdom holds that traditional bus transit services have imperceptible influences on urban form and land-use patterns because, in contrast to many rail systems, they fail to confer appreciable accessibility benefits. This is especially the case in the developed world where high levels of private automobile ownership means conventional buses are considerably slower than cars for the vast majority of trips. The exception to this rule, however, could be BRT wherein buses are provided with an exclusive, dedicated lane, signifying a significant improvement in service quality in the minds of real-estate developers and property owners (Polzin and Baltes, 2002). Levinson (2002) contends that BRT investments in Ottawa, Pittsburgh, Brisbane, and Curitiba generated land-use benefits that were as large as those that would have been created by railway investments. Vuchic (2002) expresses doubt, arguing that light-rail transit (LRT) has a significantly higher potential to impact urban form than BRT.

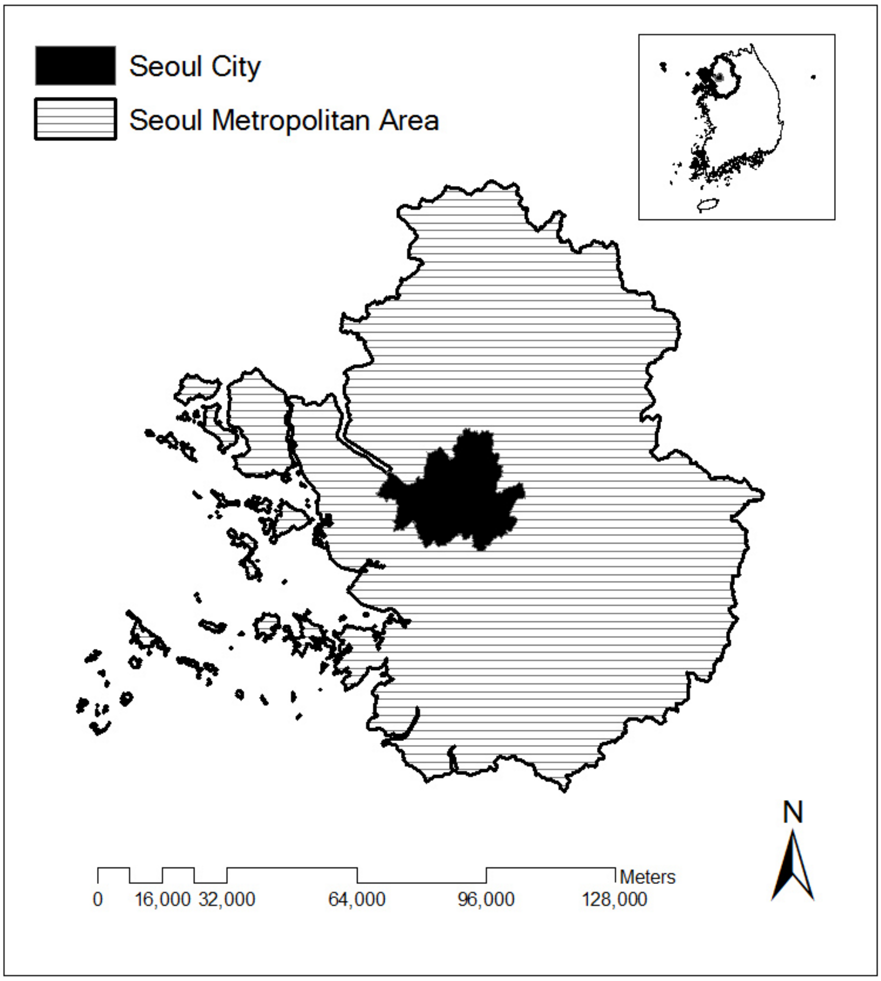
Empirical evidence that might inform this debate is quite limited. Several past studies have investigated the affects of BRT on land values. A study of dedicated-lane BRT services in Los Angeles found small negative impacts on residential property values and small gains for commercial parcels (Cervero, 2004). Land-value impacts of light-rail services in Los Angeles were found to be similar to those of BRT – i.e., slight declines in residential values and fairly small gains in commercial properties (smaller than that found for BRT). In contrast, a study of the more substantial BRT system in Bogotá, Colombia, found appreciable land-value benefits. There, multi-family housing units close to Bogotá's TransMilenio BRT rented for more per square meter than units located farther away (Rodriguez and Targa, 2004). There is also some evidence that creating pedestrian-friendly environments near BRT bus stops can further increase land-value benefits (Estupinan and Rodriguez, 2008).

Our study aims to extend past research by studying changes in both land use compositions and land values following BRT improvements over several time points. We examine impacts to both residential and non-residential properties along affected BRT corridors in Seoul. As background to the study, the next section describes both Seoul City and its current BRT services.

## 3. Background Information on BRT in Seoul

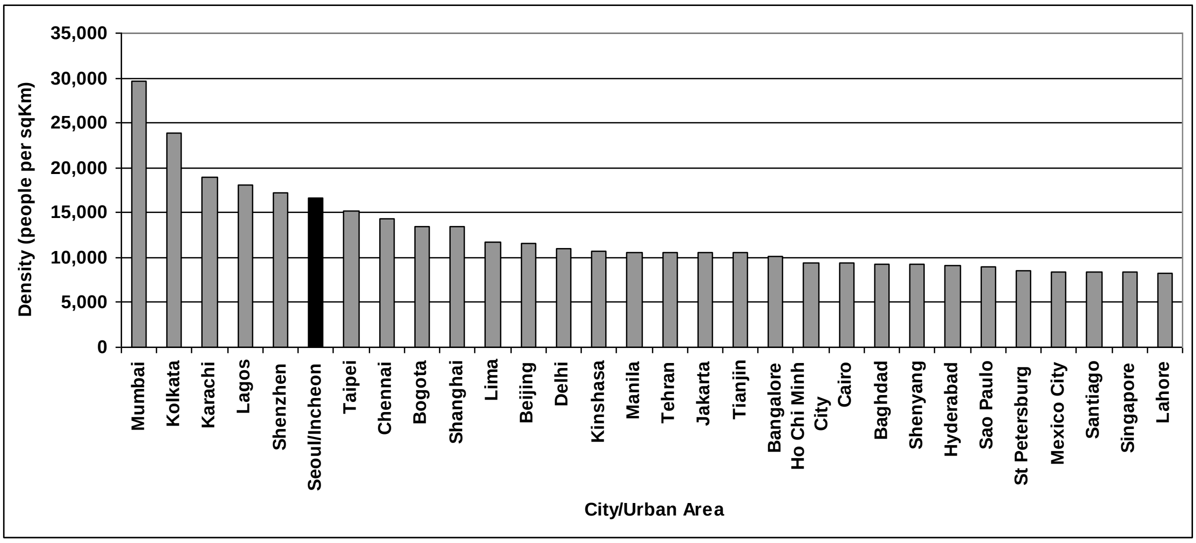
Seoul is the capital of Korea and the nation's economic, political, and cultural hub. The city itself, with more than 10 million inhabitants, is part of the Seoul Metropolitan Area (which includes Kyunggi Province and Incheon city), the world's second largest conurbation at 23 million (Figure 1). With 16,000 residents per square kilometer, Seoul and Incheon comprise the sixth densest urbanized area in the world (Figure 2).

**Figure 1. Location of Seoul, Korea**




Source: Seoul Metropolitan Government

**Figure 2. Rank Order of Population Densities Among Global Cities (2006)**

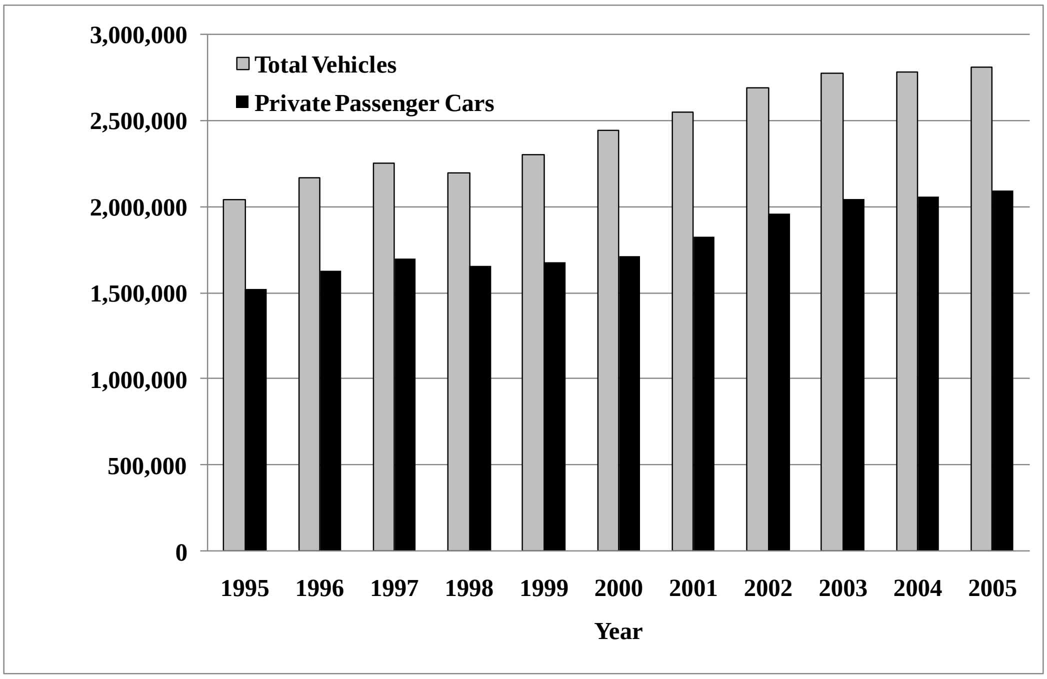



Source: City Mayors (www. citymayors.com)

Economic growth and rapid urbanization have brought about steady increases in car ownership and congestion levels in Seoul (Figures 3 and 4). Between 1995 and 2005, average motor-vehicle speeds in Seoul hovered around 20-25 km per hour, with the worst congestion during evening peak hours (Figure 5). Partly because of extreme traffic congestion as well as for income reasons, the majority of Seoul residents travel by public transport. From 2003 to 2006, more than 60% of motorized trips were by bus or subway (Figure 6).

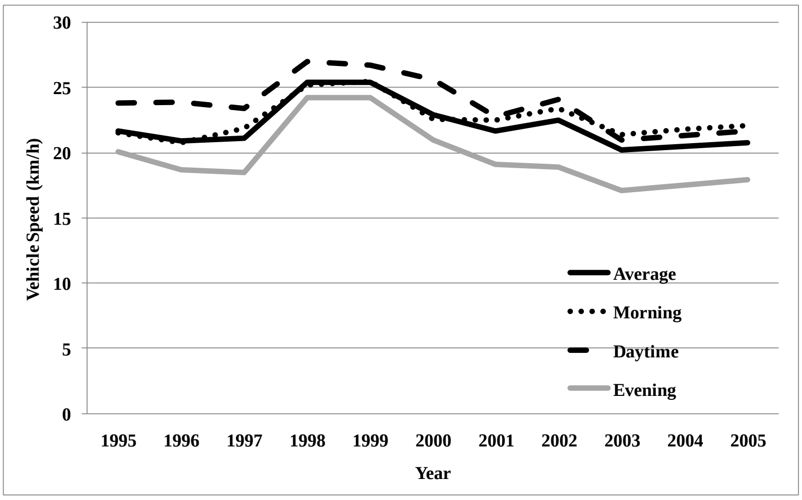
**Figure 3. Rush-Hour Traffic in Seoul**

**Figure 4. Registered Motor Vehicles in Seoul (1995~2005)**



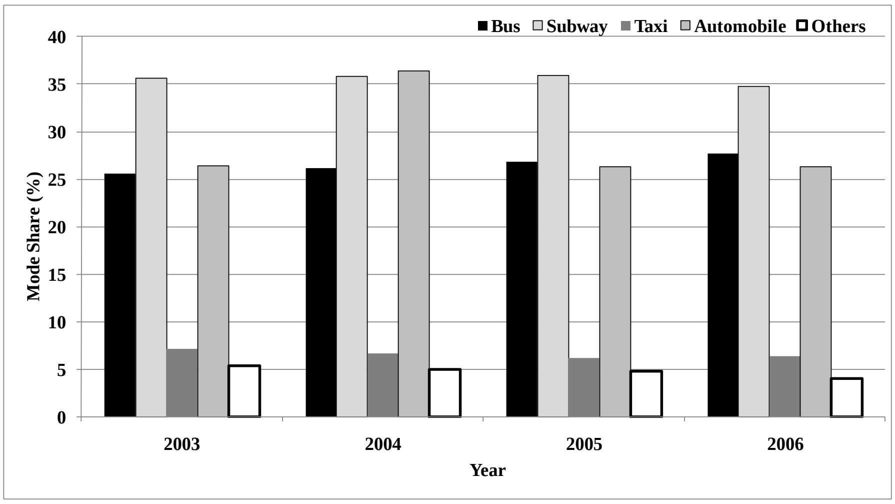

Source: Seoul Metropolitan Government

**Figure 5. Average Speeds of Motor Vehicles, 1995-2005**




Source: Seoul Metropolitan Government

**Figure 6. Modal Shares in Seoul, 2003-2006**




Source: Seoul Metropolitan Government

Because of transit's shrinking modal shares and worsening traffic congestion various bus-transit reforms were introduced in the mid-1990s, including the provision of dedicated curbside bus lanes. These improvements failed to stem bus-transit's secular declines in ridership as its modal shares fell from 30% in 1996 to 26% in 2002 (while subway's share rose from 29% to 35% during the same period). Part of the reason for bus-transit's decline was excessive competition among private operators which resulted in redundant and unstable services, the skipping of stops, and overly aggressive driving. These factors, along with rising operating deficits, prompted the Seoul Metropolitan Government to introduce a semi-public transit organization in the early 2000s that set and enforced rules and standards on bus routes, schedules, and private operating practices. Many bus routes were reorganized into a timed-transfer and pulse-scheduling arrangement. Moreover, all bus services were classified into four types of colored services: Red (long-distance and intercity services), Blue (trunk services), Green (feeder services), and Yellow (circular services). The red long-distance intercity lines linked satellite cities with each other and downtown Seoul while blue trunk lines connected between the sub-core and central-city Seoul. Green feeder buses mainly funneled passengers to subway stations and express bus stops. Yellow circular lines orbited the urban core.

Equally important was the full-scale upgrade of BRT services. During the early 2000s, Seoul's curbside bus lanes were expanded from 219km to 294km. And in mid 2004, dedicated median-lane services were introduced (Figure 7). By 2008, Seoul had installed 74 kms of median-lane BRT services spanning 8 corridors (Figure 8.). The combination of dedicated lane-services, bus-priority traffic signals, real-time passenger information systems, and attractively designed bus stops materially improved service quality.

Six months after the introduction of median-lane bus services, average bus operating speeds doubled from 11 to 22 km/hour (Seoul Development Institute, 2005a). Table 1, which compares bus versus car speeds along three road segments of the BRT network, shows bus users enjoyed substantial travel time savings relative to motorists. Other benefits included a reduction in bus-related accidents and improved schedule adherence.

**Figure 7. Bus Median Lanes in Seoul**

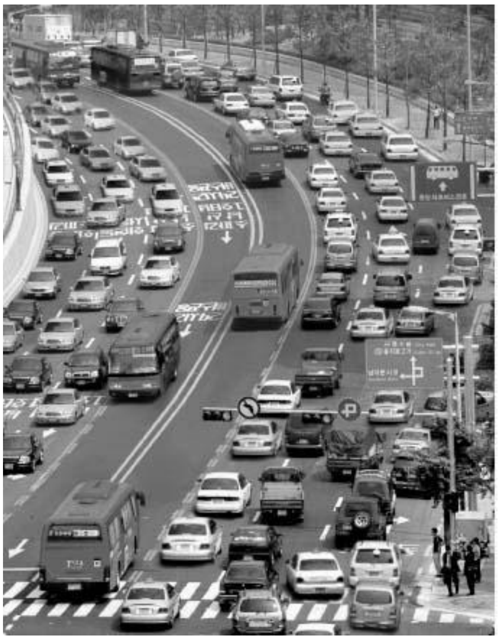
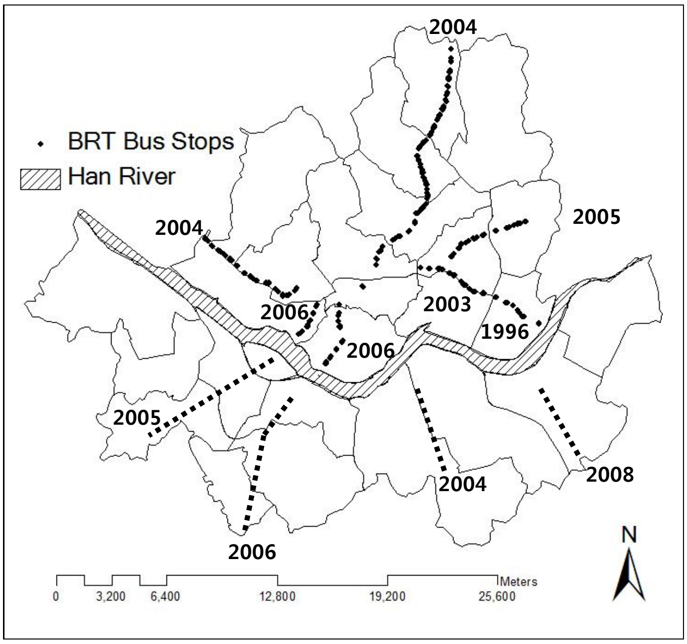


Photo: Seoul Metropolitan Government

**Figure 8. Map of BRT Corridors in Seoul.**




Source: Adapted from Seoul Metropolitan Government

**Table 1. Comparison of Operating Speeds (Km/Hr) of Cars and Buses along Three Road Segments with Exclusive Median Bus Lanes**

| Description | | Before (June 2004) | After (August 2004) | Percentage Change |
|---|---|---|---|---|
| Road A | Bus (exclusive lane) | 11 | 20.3 | 85.0% |
| | Car (other lane) | 18.5 | 19.9 | 7.6% |
| Road B | Bus (exclusive lane) | 13.1 | 22.5 | 72.0% |
| | Car (other lane) | 20.3 | 21 | 3.4% |
| Road C | Bus (exclusive lane) | 13 | 17.2 | 32.0% |
| | Car (other lane) | 18 | 19.1 | 6.1% |

Source: Seoul Development Institute (2005a)

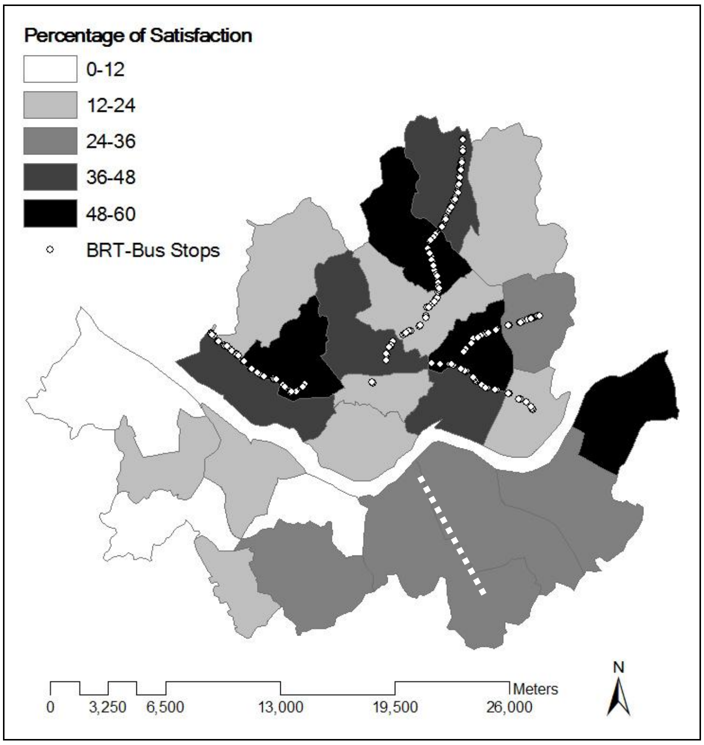
**Table 2. Number of Formal Public Complaints about Bus Services, Before and After Median-Lane BRT Services and Other Service Reforms**

| Type of Complaints | April, 2004 (Before) | December, 2004 (After) | May, 2005 (After) |
|---|---|---|---|
| Transport Card and Fare | 59,871 | 4,820 | 640 |
| Service Routes | 1,216 | 44 | 15 |
| Service Schedules | 1,638 | 141 | 29 |
| Bus Stops, Route Maps | 561 | 24 | 4 |
| Service for Bus Driver | 392 | 40 | 30 |
| Publicity of Route and Fare | 331 | 19 | 1 |
| Other (Suggestion, Transfer) | 981 | 48 | 34 |
| Total | 64,990 | 5,136 | 753 |

Source: Seoul Development Institute (2005a)

As a consequence, previous declines in bus transit's ridership were reversed, with bus patronage jumping 10% between the end of 2003 (prior to median-lane services) and the end of 2004 (after median-lane services). These ridership gains have been sustained: in 2009, bus-transit patronage outnumbered that of the subway system by more than 100,000 daily passengers; six years earlier, subways carried nearly a million more passengers per day than buses (Seoul Metropolitan Government, 2009). Not surprisingly, passenger satisfaction increased following the introduction of median bus-lanes in 2004, as shown in Table 2. And there was a clear association between where people lived and level of satisfaction. A survey of 3,000 passengers in November 2004 revealed that 28% were satisfied with overall bus service improvements. However, among those living in districts with exclusive median bus lanes, more than half said they were very satisfied with changes (Seoul Development Institute, 2005b). Figure 9 reveals the strong spatial association between where satisfied residents lived and the location of median-lane bus services.

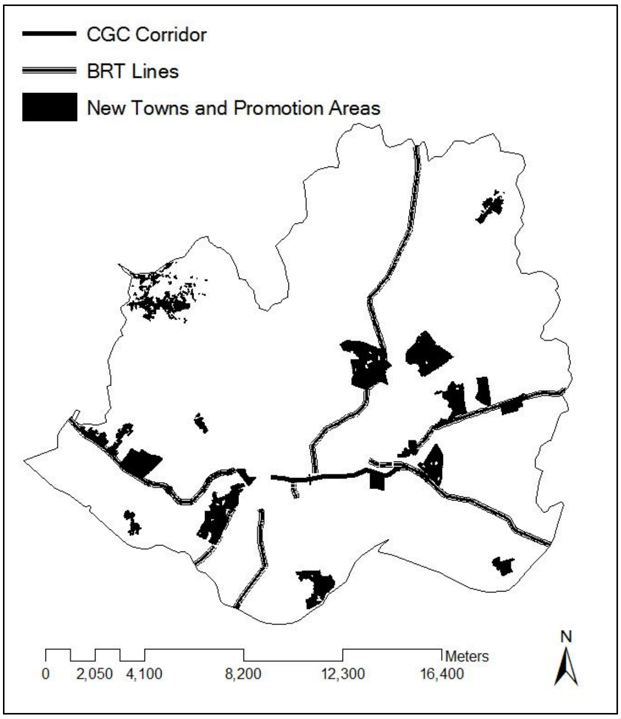
**Figure 9. Percentage of Satisfaction and Location of Bus stops**




Source: Seoul Development Institute (2005b)

In parallel to improvements in BRT services were a number of other reforms introduced under the leader of Myung-Bak Lee, former mayor of Seoul and now president of South Korea, that supported a more transit-oriented built form. One was an ambitious campaign of land reclamation, taking valuable central-city real estate given over to the private car and transforming parcels into attractive public spaces. Most noticeable was the removal of a 6-kilometer elevated freeway in the heart of Seoul, Cheong Gye Cheon (CGC), replaced by a restored urban stream and pedestrian-friendly greenway. Mayor Lee also converted a 1.3 hectare surface-street intersection in front of Seoul's City Hall with an ovalshaped grass park. Furthermore, in reaction to growing public discontent over excessively long commutes between far-flung new towns and central Seoul, local government embarked on a New Town-In Town program. Seoul's city government sought to jump-start central-city redevelopment by providing various public amenities like green space and expanding infrastructure and public services. Many of these "Promotion Areas" were sited along the median-lane BRT corridors (Figure 10).

**Figure 10. Location of New Towns-In Town and Promotion Areas along BRT Lines**




Source: Adapted from Seoul Metropolitan Government

## 4. Research Methodology and Data Sources

To study the effects of Seoul's 2004 BRT reforms on land-use activities and property values, we gathered parcel-level data for affected properties over multiple time points. Since land use is measured on a nominal scale, logit models were used to gauge the influences of BRT on discrete land-use changes. For studying impacts on the ratio-scale variable, assessed land value, we applied multiple regression techniques, specified according to hedonic price theory (Rosen, 1974). Hedonic price models apportion land-price effects based on the attributes of buildings and land as well as characteristics of surrounding neighborhoods. Since such attributes are measured at different geographic scales (e.g., parcels versus neighborhoods), as discussed later, multi-level techniques were used to estimate best-fitting models.

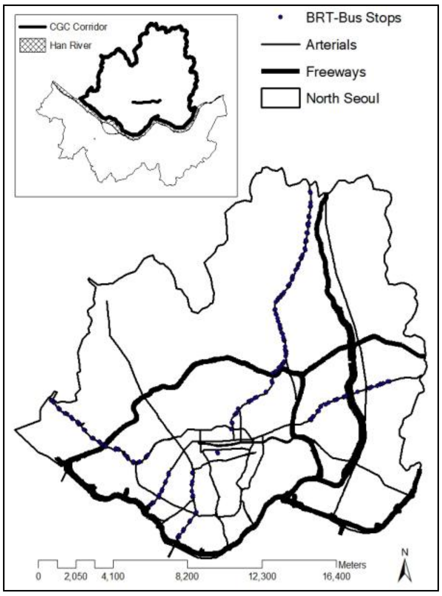
Numerous data sources were drawn upon to probe the land-use and land-value impacts of Seoul's improved BRT services. Table 3 lists and describes the key variables that were collected as well as data sources. Particularly important were data obtained from annual land surveys conducted by the Seoul Assessor Office from 2001 to 2007. For each parcel in the city, this survey provided information on street address, land use, assessed land value, and other features. Land-value data were adjusted using a Consumer Price Index (CPI) to control for inflation effects over time.

The sample frame for our research comprised land parcels whose nearest bus stop became a median-lane stop once the BRT improvements were introduced in 2004. Thus if a parcel was closer to a median-lane bus stop in 2004 than a regular bus stop, it was included in our sample; if it was closer to a regular bus stop, it was not. This yielded more than 187,000 parcel observations (the majority of which were residential properties) for model estimation. All parcels were within 2,150 meters of a BRT stop and the vast majority were within a half kilometer.

With land-parcel data in hand, point-based maps were then created to measure network and straight-line distances from each surveyed parcel to the nearest BRT stops (shown in Figure 8) as well as to major roads, subway stations, the Han River (Seoul's major north-south dividing line), and as a hub of Seoul's ambitious land reclamation and redevelopment campaign, the Cheong Gye Cheon (CGC) corridor. As Figure 11 shows, CGC was a central link in Seoul's thoroughfare network and its demolition placed demands on alternative services, including BRT, to absorb displaced traffic. The very existence of median-lane BRT was due, in part, to the lost capacity from the freeway's demolition, thus the spatial relationship of studied parcels to not only BRT stops but also the CGC corridor was of interest.

Since our models relied on information from neighborhoods that surrounded surveyed parcels, various socio-economic variables were also compiled, as shown in Table 3. Statistically, these variables served as controls, allowing us to partial out the unique effects of proximity to median-lane BRT stops on land-use and land-value changes. A variable like "Park Ratio" (a proxy for the amount of open space and greenery in an area), for instance, could be expected to increase residential property values in a crowded, congested city like Seoul. Such variables should be included in a hedonic price model to statistically remove potential confounding effects.

**Figure 11. Urban Arterials and Freeways with Reference to CGC Corridor**




Source: Adapted from Seoul Metropolitan Government

## Table 3. Variables and Data Sources for Modeling Land-Use and Land-Value Impacts

| *Variables* | *Description* | *Data Source* |
|---|---|---|
| ***Dependent Variables*** | | |
| CPI-adjusted Land Value (Korean Won/Square Meter) | Land value adjusted with CPI (2005=100) | Annual Land Survey |
| Land Use Change Types | Selected land use change=1, No change=0 | Annual Land Survey |
| | | |
| ***Independent Variables*** | | |
| ***Other Location Factors(meter)*** | | |
| Distance to CGC Corridor | Straight-line distance to CGC corridor | Calculated using GIS |
| Distance to Nearest CGC Freeway Ramp | Straight-line distance to CGC elevated freeway ramp | Calculated using GIS |
| Network Distance to Nearest CGC Freeway Ramp | Distance along network to CGC elevated freeway ramp | Calculated using GIS |
| Distance to Nearest CGC Greenway Pedestrian Entrances | Straight-line distance to pedestrian entrances on CGC urban greenway | Calculated using GIS |
| Network Distance to Nearest CGC Greenway Pedestrian Entrances | Distance along network to pedestrian entrances on CGC urban greenway | Calculated using GIS |
| Distance to CBD: City Hall | Straight-line distance to Seoul's City Hall | Calculated using GIS |
| Distance to Nearest Subway Stations | Straight-line distance to nearest subway stations | Calculated using GIS |
| Distance to Arterial Roads | Straight-line distance to arterial roads | Calculated using GIS |
| Distance to Bus Stops | Straight-line distance to bus stops | Calculated using GIS |
| Network Distance to Bus Stops | Distance along network to bus stops | Calculated using GIS |
| Distance to Han River | Straight-line distance to Han River | Calculated using GIS |
| Job Accessibility within 30 minutes by Car | Number of jobs within 30 minutes by car | Calculated using GIS |
| | | |
| ***Land Attributes, Use, and Regulation*** | | |
| CPI-adjusted Land Value (Korean Won/Square Meter) | Land value adjusted with CPI (2005=100) | Annual Land Survey |
| Land Use | Land use types (residential and non-residential) | Annual Land Survey |
| Building Coverage Ratio | Ratio of floor area to total land area | Seoul Zoning Map |
| Floor Area Ratio | Ratio of total building area to floor area | Seoul Zoning Map |
| | | |
| ***Neighborhood Economic and Demographic Attributes*** | | |
| Population Density | Number of population per total district area | Seoul Statistics |
| Employment Density | Number of employment per gross Ward area | Seoul Statistics |
| Age Structure | Proportion of 20~40, 40~60, and more than 60 per people more than 20 years of age | Seoul Statistics |
| Proportion of College Degree | Proportion of people with college degree per people more than 20 years of age | Population and Housing Census |
| | | |
| ***Other Neighborhood Attributes*** | | |
| Park Ratio | Park area per gross Ward area | Seoul Statistics |
| Developed Land Ratio | Land for building, school, and road per gross Ward area | Seoul Statistics |
| Road Area Ratio | Total road area per gross Ward area | Seoul Statistics |
| Retail Area Ratio | Total retail building area per gross Ward area | Seoul Statistics |
| Proportion of Residential Permit in Total Permit | Total area of residential permit per gross permit area | Seoul Statistics |
| Proportion of Commercial Permit in Total Permit | Total area of commercial permit per gross permit area | Seoul Statistics |
| CPI-adjusted Local Tax per Households (Korean Won) | CPI-adjusted local tax per households (2005=100) | Seoul Statistics |

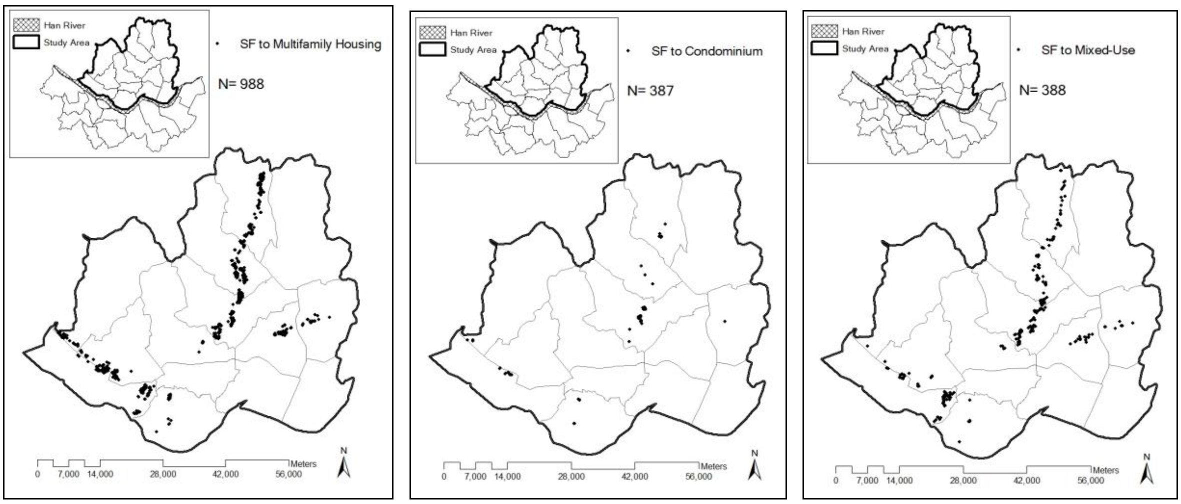
## 5. Land Use Change Models

This section examines how Seoul's introduction of median-lane BRT improvements in mid-2004 affected land uses. Multilevel binary logit models were used to predict three types of conversions from single-family residences: to multi-family residential rental units, to condominium owner-occupied units, and to mixed-parcels which typically involved a combination of commercial activities (e.g., retail, services, offices) and sometimes residential as well. All of these changes correspond to what might be considered an intensification of activities on parcels, from single-family residences to often higher density activities (i.e., more units in the form of multi-family housing and condominiums; adding of retail activities).

To the property owner, intensification normally translates into higher valued properties and in some cases increases rental income. We note that there were insufficient observations to model other possible land-use conversions, such as from retail-to-offices or undeveloped-to-retail.

The land use statuses of more than 52,000 single-family residential parcels that were part of our sample frame were tracked for the 2001 to 2007 period. More than 96 percent of parcels remained in single-family use over this six-year period. Among the remaining parcels, the dominant conversion was to multi-family housing followed by mixed land uses and condominiums. Figure 12 shows the locations of converted parcels, all aligned fairly close to BRT stops.

**Figure 12. Location of Converted Single-Family Residential Parcels**




**Multi-family Conversions** **Condominium Conversions** **Mixed Use Conversions**

Source: Adapted from Seoul Metropolitan Government

## 5.1 Model Structure

Multilevel logit models were used to estimate factors influencing the three land-use conversions. Multilevel modeling accounts for the fact that parcels from the same neighborhood share common attributes like local road-network designs and demographic characteristics. Failure to account for shared upper-level (i.e., neighborhood) attributes of lower-level (i.e., parcel) observations can bias parameter estimates. Our multilevel models incorporated both fixed and random effects. Fixed effects represent variable coefficients that are constant across upper-level (i.e., neighborhoods) units while random effects indicate error-terms that vary across upper level units. Estimated multilevel models of land-use conversion took the following form:

$$y_{ij} = \gamma_{00} + \beta_1 L_{ij} + \beta_2 S_{ij} + \beta_4 N_{ij} + \mu_{0j} + \varepsilon_{ij} \qquad (1)$$

Where:

$y_{ij}$ = 1 if single-family parcel i (Level 1) in neighborhood j (Level 2) changed use; otherwise 0;

$\gamma_{00}$ = model constant;

$L_{ij}$ = a vector of location attributes (e.g., distance to bus stops) of parcel i (Level 1) in neighborhood j (Level 2);

$S_{ij}$ = a vector of neighborhood socio-demographic characteristics (e.g., population density, education level) in neighborhood j (Level 2) for parcel i (Level 1) in that neighborhood;

$N_{ij}$ = a vector of neighborhood land-use (e.g., share of parcels in retail use) and public expenditure (e.g., local tax per household) in neighborhood j (Level 2) that is assigned to each parcel i (Level 1) in the neighborhood; and

$\mu_{0j}$, $\varepsilon_{ij}$ = residual error terms of level-2 and level-1, respectively.

An important output of multilevel models is the intraclass correlation (ICC), which measures the relative variation in THE estimated dependent variable between versus within neighborhoods. High ICC values, typically above 0.05 and with statistically significant probability levels, indicate individual parcels tend to share neighborhood attributes, signifying the need for multilevel estimation (Rabe-Hesketh and Skrondal, 2008).

**5.2 Model Results**

Table 4 presents the multilevel model results for the most dominant conversion – single-family to multi-family residential – and Table 5 shows the output for the two other land-use changes studied: single-family to condominiums and to mixed uses. Slightly better model fits were obtained when expressing ratio-scale explanatory variables in natural logarithmic form, thus these model results are presented. Models were specified according to the multilevel structure described earlier in equation 1.

Of most interest to our research is the affects of "Distance to Bus Stops" on land-use conversions. For all single-family parcels in the sample frame, Tables 4 and 5 reveal that parcels within ½ kilometer of a stop (generally associated with a walk of under 5 minutes) were generally more likely to convert to more intensive uses relative to parcels beyond ½ kilometer. Impacts across 100 meter distance bands were hardly simple, as plotted in Figure 13, and at this juncture, we can only speculate why. Notably, the higher-end conversions – to condominiums and mixed-use buildings – were actually less likely to occur within the immediate vicinity of a bus stop (i.e., < 100m). This could be due to the nuisance effect of being located near busy BRT and roadway corridors (e.g., people walking to and congregating around bus stops; noise impacts). Multi-family conversions, however, seemed immune to this nuisance effects. Beyond a buffer distance of 100 meters to a stop, single-family conversions were more likely to occur. At around 400 meters, the influences of distance to a bus stop on land-use conversions largely evaporated.

**Table 4. Multilevel Logit Model for Predicting Single Family Housing to Multi-Family Conversions**

| | SF to Multi Family Housing | | |
|---|---|---|---|
| Variables | Coefficient | t | p |
| Fixed Effects | | | |
| *Distance to Bus Stops* | | | |
| dummy (1, if Distance ≤ 100m, otherwise 0) | 1.253 | 2.320 | 0.020 |
| dummy (1, if 100 < Distance ≤ 200m, otherwise 0) | 1.657 | 3.150 | 0.002 |
| dummy (1, if 200 < Distance ≤ 300m, otherwise 0) | 1.699 | 3.290 | 0.001 |
| dummy (1, if 300 < Distance ≤ 400m, otherwise 0) | 1.999 | 3.920 | 0.000 |
| dummy (1, if 400 < Distance ≤ 500m, otherwise 0) | −0.120 | −0.190 | 0.851 |
| | | | |
| *Other Location Factors* | | | |
| ln(Network Distance to CGC Corridor) | 0.078 | 0.130 | 0.898 |
| ln(Distance to CBD: City Hall) | 0.900 | 1.300 | 0.194 |
| ln(Distance to Nearest Subway Stations) | 0.032 | 0.350 | 0.726 |
| ln(Distance to Arterial Roads) | −0.130 | −3.450 | 0.001 |
| | | | |
| *Neighborhood Economic and Demographic Attributes* | | | |
| ln(CPI-adjusted Land Value) | −1.462 | −9.950 | 0.000 |
| ln(Population Density) | 0.607 | 2.410 | 0.016 |
| ln(Employment Density) | −0.661 | −0.380 | 0.703 |
| ln(Proportion of College Degree) | 1.233 | 2.500 | 0.012 |
| ln(Proportion of 40 to 60 years old) | 0.766 | 0.490 | 0.622 |
| ln(Proportion of more than 60 years old) | 0.352 | 0.220 | 0.823 |
| | | | |
| *Other Neighborhood Attributes* | | | |
| ln(Park Density Ratio) | −0.349 | −1.220 | 0.223 |
| ln(Developed Land Ratio) | 1.778 | 1.240 | 0.214 |
| ln(Road Area Ratio) | −0.897 | −0.290 | 0.774 |
| ln(Retail Area Ratio) | −0.233 | −1.210 | 0.226 |
| ln(Proportion of Residential Permit per Total Permit) | 0.241 | 0.780 | 0.438 |
| ln(Proportion of Commercial Permit per Total Permit) | 1.010 | 1.260 | 0.207 |
| ln(CPI-adjusted Local Tax per Households) | 0.859 | 0.790 | 0.428 |
| ln(Job Accessibility within 30 minutes by Car) | −0.395 | −0.630 | 0.526 |
| | | | |
| Constant | 1.846 | 0.110 | 0.910 |
| Random Effects | | | |
| Standard Deviation of the Random Intercept | 0.718 | | |
| ICC | 0.136 | | |
| Summary Statistics | | | |
| Number of Parcel Observations (Level 1) | 25,410 | | |
| Number of Neighborhood Groups (Level 2) | 72 | | |

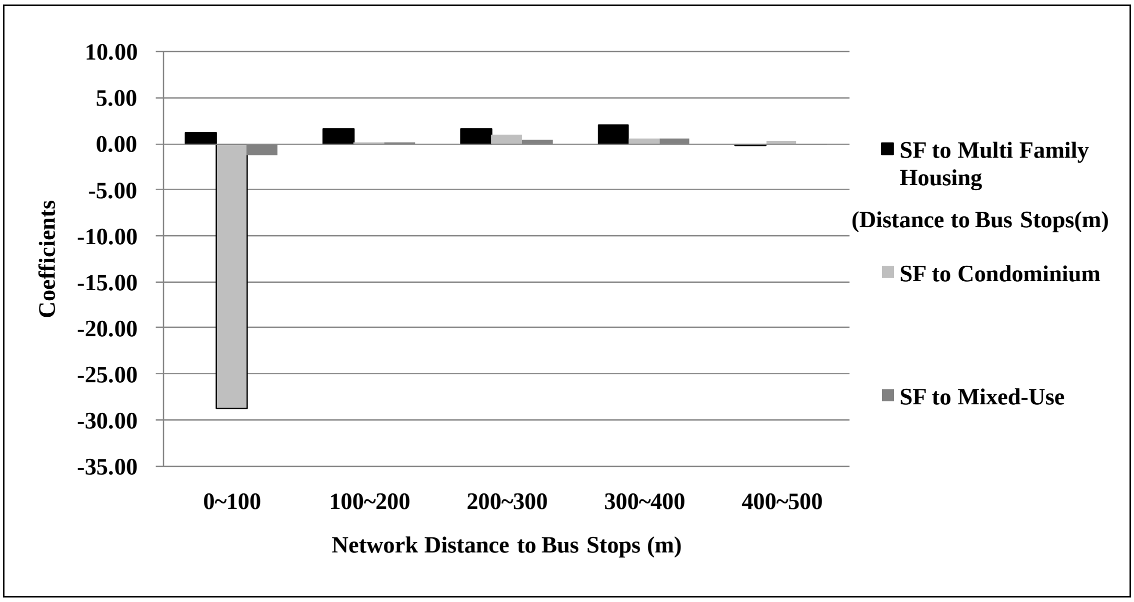
**Table 5. Multilevel Logit Model for Predicting Single Family Housing to Condominium and Mixed-Use Conversions**

| Variables | SF to Condominium | | | SF to Mixed-use | | |
|---|---|---|---|---|---|---|
| | Coefficient | t | p | Coefficient | t | p |
| Fixed Effects | | | | | | |
| *Network Distance to Bus Stops* | | | | | | |
| dummy (1, if Network Distance ≤ 100m, otherwise 0) | −28.826 | 0.000 | 1.000 | −1.185 | −2.890 | 0.004 |
| dummy (1, if 100 < Network Distance ≤ 200m, otherwise 0) | 0.173 | 0.310 | 0.754 | 0.024 | 0.110 | 0.913 |
| dummy (1, if 200 < Network Distance ≤ 300m, otherwise 0) | 1.023 | 2.370 | 0.018 | 0.431 | 2.170 | 0.030 |
| dummy (1, if 300 < Network Distance ≤ 400m, otherwise 0) | 0.565 | 1.450 | 0.147 | 0.541 | 2.740 | 0.006 |
| dummy (1, if 400 < Network Distance ≤ 500m, otherwise 0) | 0.342 | 0.900 | 0.367 | −0.087 | −0.390 | 0.698 |
| | | | | | | |
| *Other Location Factors* | | | | | | |
| ln(Network Distance to CGC Corridor) | 7.127 | 2.290 | 0.022 | 0.959 | 1.270 | 0.204 |
| ln(Distance to CBD: City Hall) | −22.832 | −4.940 | 0.000 | −1.310 | −1.770 | 0.077 |
| ln(Distance to Nearest Subway Stations) | 0.805 | 2.340 | 0.019 | 0.462 | 3.720 | 0.000 |
| ln(Distance to Arterial Roads) | 1.112 | 6.060 | 0.000 | −0.262 | −4.830 | 0.000 |
| ln(Distance to Bus Stops) | 1.271 | 4.070 | 0.000 | | | |
| | | | | | | |
| *Neighborhood Economic and Demographic Attributes* | | | | | | |
| ln(CPI-adjusted Land Value) | 2.310 | 6.540 | 0.000 | 0.609 | 4.040 | 0.000 |
| ln(Building Coverage Ratio) | | | | −0.297 | −0.430 | 0.665 |
| ln(Floor Area Ratio) | | | | 0.411 | 2.600 | 0.009 |
| ln(Population Density) | −7.614 | −3.230 | 0.001 | 0.053 | 0.170 | 0.867 |
| ln(Employment Density) | −46.629 | −0.030 | 0.976 | 3.495 | 1.280 | 0.199 |
| ln(Proportion of College Degree) | 12.475 | 2.140 | 0.032 | 0.602 | 0.930 | 0.353 |
| ln(Proportion of 40 to 60 years old) | −22.523 | −1.500 | 0.134 | −0.826 | −0.390 | 0.697 |
| ln(Proportion of more than 60 years old) | −46.801 | −2.260 | 0.024 | −5.827 | −2.840 | 0.005 |
| | | | | | | |
| *Other Neighborhood Attributes* | | | | | | |
| ln(Park Density Ratio) | −0.351 | 0.000 | 0.999 | 0.080 | 0.230 | 0.816 |
| ln(Developed Land Ratio) | −106.385 | −0.030 | 0.976 | −0.172 | −0.100 | 0.922 |
| ln(Road Area Ratio) | 95.790 | 0.030 | 0.979 | −3.801 | −0.850 | 0.393 |
| ln(Retail Area Ratio) | 2.598 | 0.010 | 0.990 | 0.505 | 1.440 | 0.149 |
| ln(Proportion of Residential Permit per Total Permit) | 13.544 | 0.040 | 0.968 | 0.723 | 1.460 | 0.144 |
| ln(Proportion of Commercial Permit per Total Permit) | −20.038 | −0.020 | 0.984 | −0.721 | −0.850 | 0.396 |
| ln(CPI-adjusted Local Tax per Households) | 22.288 | 0.010 | 0.991 | −2.054 | −1.340 | 0.179 |
| ln(Job Accessibility within 30 minutes by Car) | | | | | | |
| | | | | | | |
| Constant | 277.969 | 0.020 | 0.983 | −28.466 | −1.610 | 0.108 |
| Random Effects | | | | | | |
| Standard Deviation of the Random Intercept | 4.886 | | | 1.002 | | |
| ICC | 0.879 | | | 0.234 | | |
| Summary Statistics | | | | | | |
| Number of Parcel Observations (Level 1) | 2,387 | | | 24,810 | | |
| Number of Neighborhood Groups (Level 2) | 65 | | | 72 | | |

Among other location variables, distance to arterial roads had the strongest influence on land-use conversions; the likelihood of switching to multi-family and mixed uses fell with distance to arterial roads. Other distance variables (e.g., to city hall and subways) were statistically associated with condominiums and mixed uses conversions, albeit in no clearly discernible pattern.

Among the remaining variables, higher assessed land values of a neighborhood significantly increased the odds of converting single-family residences to the higher end uses: condominiums and mixed uses. Property owners seemed particularly inclined to convert residences to condominiums, the most popular high-rise housing in Korea, in settings with relatively high average land values as well as college-educated residents. Less appealing in higher valued core areas of the city were conversions to multi-family housing. Table 5 also shows that higher permissible floor area ratios of a neighborhood contributed to mixed-use conversions. Most other control variables in Tables 4 and 5 were not statistically significant but were retained so as to apply consistent sets of explanatory variables across all models.

**Figure 13. Coefficients of Each Land Use Change by Distance Intervals**




## 6. Land Value Models

A similar multilevel modeling approach was adopted for studying the land-value capitalization effects of Seoul's BRT improvements. The primary change to equation 1, shown earlier, was the use of assessed land values as the left-hand-side dependent variable. Using land valuation data from Seoul's Assessors Office, multilevel multiple regression models were estimated for residential and non-residential properties over two time periods:

2001-2004 (pre-BRT) and 2005-2007 (post-BRT). Since land values are assessed in Seoul in the early part of the calendar year, the 2004 valuations were made prior to the mid-2004 initiation of median-lane BRT services.

Multilevel regression models were estimated in log-log form because of the better statistical fits than linear formulations and the need to moderate the effects of heteroschedastic error terms. In the models that follow, all ratio-scale variables were converted to natural logarithms. A side benefit of log-log formulations is that estimated coefficients represent elasticities, revealing the relative sensitivity of land values to changes in the right-hand side predictor variables. The models shown in this section also produced the best fits consistent with hedonic price theory.

### 6.1 Non-Residential Hedonic Price Models

A total of 37,515 and 23,969 non-residential land-parcel observations were available, respectively, for the two periods (2001-2004 and 2005-2007). For both periods, non-residential parcels were comprised as follows: commercial-retail (55.2%), office (3.3%), undeveloped land zoned for commercial-retail (3.1%), mixed-use (37.6%), and undeveloped land zoned for mixed-use (0.7%). The parcels ranged in value per $m^2$ from 637,000 Korean Won (US$500) to 45 million Korean Won (over US$35,000) over the 2001-2007 period.

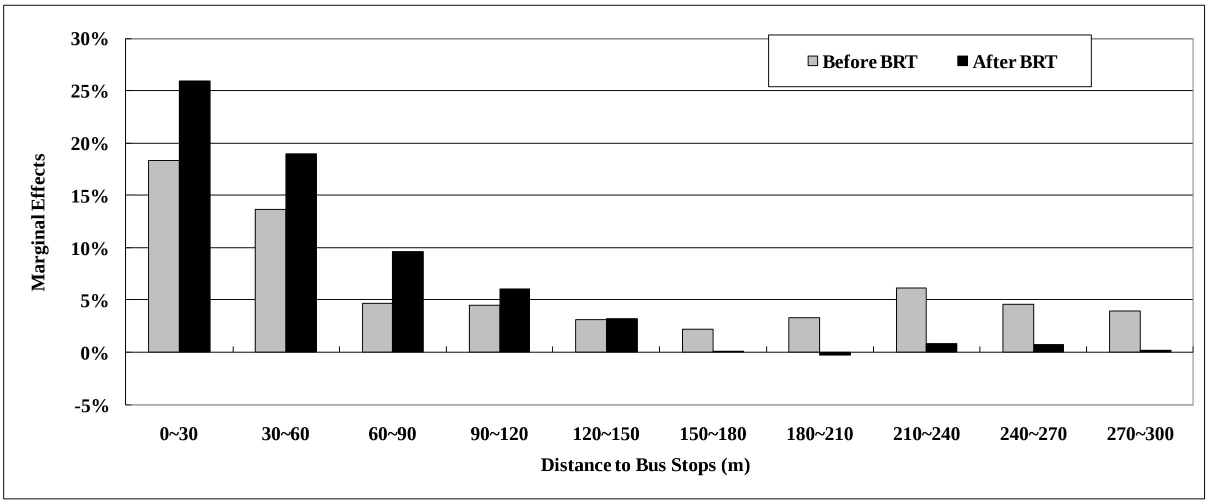
The multilevel models estimated for non-residential parcels are shown in Table 6. The intraclass correlations, indicating the share of variation explained by the grouping structure, were quite high, justifying the use of multilevel model estimation. Notably, 72.2 % and 88.9 % of the variation in land values is explained by between-group variation among 71 and 70 neighborhoods over the two time periods, respectively. In both models shown in Table 6, most predictor variables were statistically significant at the 5 percent probability level.

**Table 6. Multilevel Hedonic Model for Predicting**
**Non Residential Land Value per Square Meter**
**Note: 1 Korean Won = 0.0011 U.S. Dollar in 2007**

| | 2001~2004 | | | 2005~2007 | | |
|---|---|---|---|---|---|---|
| Variables | Coefficient | t | p | Coefficient | t | p |
| Fixed Effects | | | | | | |
| *Distance to Bus Stops* | | | | | | |
| dummy (1, if Distance ≤ 30m, otherwise 0) | 0.183 | 14.440 | 0.000 | 0.260 | 16.390 | 0.000 |
| dummy (1, if 30 < Distance ≤ 60m, otherwise 0) | 0.137 | 11.790 | 0.000 | 0.189 | 13.160 | 0.000 |
| dummy (1, if 60 < Distance ≤ 90m, otherwise 0) | 0.047 | 4.110 | 0.000 | 0.096 | 6.790 | 0.000 |
| dummy (1, if 90 < Distance ≤ 120m, otherwise 0) | 0.045 | 3.950 | 0.000 | 0.061 | 4.290 | 0.000 |
| dummy (1, if 120 < Distance ≤ 150m, otherwise 0) | 0.031 | 2.730 | 0.006 | 0.033 | 2.290 | 0.022 |
| dummy (1, if 150 < Distance ≤ 180m, otherwise 0) | 0.022 | 1.970 | 0.049 | 0.001 | 0.040 | 0.969 |
| dummy (1, if 180 < Distance ≤ 210m, otherwise 0) | 0.033 | 2.810 | 0.005 | −0.003 | −0.210 | 0.837 |
| dummy (1, if 210 < Distance ≤ 240m, otherwise 0) | 0.061 | 4.940 | 0.000 | 0.008 | 0.510 | 0.609 |
| dummy (1, if 240 < Distance ≤ 270m, otherwise 0) | 0.045 | 3.430 | 0.001 | 0.008 | 0.470 | 0.640 |
| dummy (1, if 270 < Distance ≤ 300m, otherwise 0) | 0.040 | 2.610 | 0.009 | 0.002 | 0.090 | 0.928 |
| | | | | | | |
| *Other Location Factors* | | | | | | |
| ln(Network Distance to Nearest CGC Freeway Ramps) | −0.804 | −23.250 | 0.000 | | | |
| ln(Network Distance to Nearest CGC Greenway Pedestrian Entrances) | | | | −0.743 | −20.880 | 0.000 |
| ln(Distance to CBD: City Hall) | 0.348 | 7.450 | 0.000 | 0.265 | 4.550 | 0.000 |
| ln(Distance to Nearest Subway Stations) | −0.087 | −30.470 | 0.000 | −0.123 | −34.200 | 0.000 |
| ln(Distance to Arterial Roads) | −0.013 | −6.770 | 0.000 | −0.001 | −0.260 | 0.793 |
| | | | | | | |
| *Land Use and Regulation* | | | | | | |
| Office (0/1) | 0.059 | 7.190 | 0.000 | 0.041 | 3.410 | 0.001 |
| Commercial Raw Lands (0/1) | −0.090 | −10.660 | 0.000 | −0.011 | −1.010 | 0.314 |
| Mixed-Use (0/1) | −0.374 | −90.670 | 0.000 | −0.460 | −91.840 | 0.000 |
| Mixed-Use Raw Lands (0/1) | −0.466 | −24.410 | 0.000 | −0.543 | −26.950 | 0.000 |
| ln(Building Coverage Ratio) | 0.079 | 4.680 | 0.000 | | | |
| ln(Floor Area Ratio) | 0.217 | 58.540 | 0.000 | | | |
| | | | | | | |
| *Neighborhood Economic and Demographic Attributes* | | | | | | |
| ln(Population Density) | −0.102 | −3.640 | 0.000 | 0.110 | 4.930 | 0.000 |
| ln(Employment Density) | −0.792 | −17.580 | 0.000 | −0.138 | −0.880 | 0.377 |
| ln(Proportion of College Degree) | 0.234 | 1.920 | 0.055 | 0.565 | 1.860 | 0.063 |
| ln(Proportion of 40 to 60 years old) | −0.025 | −1.610 | 0.108 | 0.485 | 4.620 | 0.000 |
| ln(Proportion of more than 60 years old) | 0.108 | 4.460 | 0.000 | 0.268 | 4.190 | 0.000 |
| | | | | | | |
| *Other Neighborhood Attributes* | | | | | | |
| ln(Park Density Ratio) | 0.110 | 15.390 | 0.000 | 0.355 | 15.160 | 0.000 |
| ln(Developed Land Ratio) | −1.132 | −4.020 | 0.000 | −3.396 | −4.010 | 0.000 |
| ln(Road Area Ratio) | 2.946 | 11.870 | 0.000 | 2.196 | 2.520 | 0.012 |
| ln(Retail Area Ratio) | 0.065 | 9.890 | 0.000 | −0.021 | −4.630 | 0.000 |
| ln(Proportion of Residential Permit per Total Permit) | −0.108 | −19.020 | 0.000 | −0.040 | −7.230 | 0.000 |
| ln(Proportion of Commercial Permit per Total Permit) | 0.031 | 6.230 | 0.000 | 0.070 | 13.500 | 0.000 |
| | | | | | | |
| Constant | 33.662 | 39.810 | 0.000 | 25.527 | 9.310 | 0.000 |
| Random Effects | | | | | | |
| ICC | 0.722 | | | 0.889 | | |
| Summary Statistics | | | | | | |
| Number of Parcel Observations (Level 1) | 37,515 | | | 23,969 | | |
| Number of Neighborhood Groups (Level 2) | 71 | | | 70 | | |

The coefficients on dummy variables for distance to the nearest BRT stops speak to the core research question: whether proximity affects land prices differently before and after the BRT improvements. Figure 14 plots these coefficients, revealing the marginal effects of proximity on land prices, expressed in percentage terms and over 30 meter distance bands, relative to parcels more than 300 meters away. While there were general proximity benefits in both periods, Figure 14 reveals the benefits were more prominently capitalized into land values in the post-period (2005-2007). Impacts were particularly notable within 150 meters of the nearest bus stop.

**Figure 14. Marginal Effects of BRT Bus Stops on Non-Residential Land Values by Distance Intervals**




Other control variables in Table 6 generally conform to expectations. Land prices fell with distance to the nearest CGC freeway ramps (when they existed in 2001-2004) as well as the nearest CGC greenway pedestrian entrances (in the post-freeway period of 2005-2007). They also fell with distance to another important infrastructure component, Seoul's world-class subway system. Table 6 also shows offices enjoyed higher land-value premiums than other non-residential uses, *ceteris paribus,* and site density (as reflected by building coverage and floor-area-ratio) also worked in favor of higher land values (though only in the pre-BRT period). While the signs on some control variables, such as "Park Density Ratio" (reflecting the benefit of having parks in the neighborhoods), make sense, the signs on others are less easy to explain and likely reflect local idiosyncrasies of Seoul's commercial real-estate market.

## 6.2 Residential Hedonic Price Models

In all, data for 85,124 and 41,302 residential parcels were available for the two periods. For both periods, residential parcels were used as follows: single-family housing (81.9%), multi-family housing (11.5%), undeveloped land zoned for residential (3.7%), condominiums (1.7%), and row housing (1.3%). Residential parcels ranged in value per $m^2$ from 148,000 Korean Won (US$32) to more than 8,400,000 Korean Won (US$6,600) over the 2001-2007 period.

The multilevel models estimated for residential parcels are shown in Table 7. The high intraclass correlations justified the use of multilevel model estimation: 99.2% and 99.5% of the variation in land values is explained by the between-group variation across the 65 neighborhoods over the two time periods, respectively. Nearly all predictor variables in both models are statistically significant at the .01 probability level.

## Table 7. Multilevel Hedonic Model for Predicting Residential Land Value per Square Meter

**Note: 1 Korean Won = 0.0011 U.S. Dollar in 2007**

| | 2001~2004 | | | 2005~2007 | | |
|---|---|---|---|---|---|---|
| Variables | Coefficient | t | p | Coefficient | t | p |
| Fixed Effects | | | | | | |
| *Distance to Bus Stops* | | | | | | |
| dummy (1, if distance ≤ 30m, otherwise 0) | −0.025 | −3.710 | 0.000 | 0.103 | 11.050 | 0.000 |
| dummy (1, if 30 < distance ≤ 60m, otherwise 0) | 0.015 | 4.150 | 0.000 | 0.115 | 22.510 | 0.000 |
| dummy (1, if 60 < distance ≤ 90m, otherwise 0) | 0.022 | 8.200 | 0.000 | 0.105 | 26.230 | 0.000 |
| dummy (1, if 90 < distance ≤ 120m, otherwise 0) | 0.022 | 9.290 | 0.000 | 0.089 | 25.080 | 0.000 |
| dummy (1, if 120 < distance ≤ 150m, otherwise 0) | 0.026 | 12.020 | 0.000 | 0.082 | 24.980 | 0.000 |
| dummy (1, if 150 < distance ≤ 180m, otherwise 0) | 0.025 | 12.010 | 0.000 | 0.070 | 22.280 | 0.000 |
| dummy (1, if 180 < distance ≤ 210m, otherwise 0) | 0.028 | 13.620 | 0.000 | 0.063 | 20.250 | 0.000 |
| dummy (1, if 210 < distance ≤ 240m, otherwise 0) | 0.021 | 10.230 | 0.000 | 0.054 | 17.070 | 0.000 |
| dummy (1, if 240 < distance ≤ 270m, otherwise 0) | 0.016 | 7.520 | 0.000 | 0.053 | 15.920 | 0.000 |
| dummy (1, if 270 < distance ≤ 300m, otherwise 0) | 0.004 | 1.560 | 0.118 | 0.053 | 14.630 | 0.000 |
| | | | | | | |
| | | | | | | |
| *Other Location Factors* | | | | | | |
| ln(Network Distance to Bus Stops) | −0.052 | −42.050 | 0.000 | −0.030 | −16.370 | 0.000 |
| ln(Network Distance to Nearest CGC Freeway Ramps) | −0.027 | −1.990 | 0.047 | | | |
| ln(Network Distance to Nearest CGC Greenway Pedestrian Entrances) | | | | −0.154 | −8.320 | 0.000 |
| ln(Distance to CBD: City Hall) | −0.004 | −0.250 | 0.800 | 0.081 | 3.380 | 0.001 |
| ln(Distance to Nearest Subway Stations) | −0.025 | −20.720 | 0.000 | −0.046 | −25.560 | 0.000 |
| ln(Distance to Arterial Roads) | −0.049 | −91.310 | 0.000 | −0.044 | −53.010 | 0.000 |
| ln(Distance to Han River) | 0.007 | 0.900 | 0.366 | −0.379 | −27.000 | 0.000 |
| | | | | | | |
| *Land Use and Regulation* | | | | | | |
| Row Housing (0/1) | 0.084 | 19.410 | 0.000 | 0.098 | 17.230 | 0.000 |
| Multi Family Housing (0/1) | 0.041 | 25.850 | 0.000 | 0.051 | 24.520 | 0.000 |
| Condominium (0/1) | 0.382 | 80.200 | 0.000 | 0.251 | 58.380 | 0.000 |
| Residential Raw Lands (0/1) | −0.029 | −11.010 | 0.000 | −0.082 | −22.910 | 0.000 |
| ln(Building Coverage Ratio) | 0.167 | 41.250 | 0.000 | | | |
| ln(Floor Area Ratio) | 0.105 | 53.970 | 0.000 | | | |
| | | | | | | |
| *Neighborhood Economic and Demographic Attributes* | | | | | | |
| ln(Population Density) | 0.162 | 16.110 | 0.000 | 0.095 | 8.040 | 0.000 |
| ln(Employment Density) | 0.343 | 16.830 | 0.000 | −1.159 | −12.840 | 0.000 |
| ln(Proportion of College Degree) | −0.010 | −0.020 | 0.980 | 1.890 | 2.680 | 0.007 |
| ln(Proportion of 40 to 60 years old) | −0.090 | −12.980 | 0.000 | 0.596 | 11.210 | 0.000 |
| ln(Proportion of more than 60 years old) | 0.176 | 19.510 | 0.000 | 0.598 | 19.930 | 0.000 |
| | | | | | | |
| *Other Neighborhood Attributes* | | | | | | |
| ln(Park Density Ratio) | 0.037 | 15.790 | 0.000 | 0.261 | 17.310 | 0.000 |
| ln(Developed Land Ratio) | 4.547 | 13.930 | 0.000 | −9.928 | −22.610 | 0.000 |
| ln(Road Area Ratio) | 5.139 | 43.920 | 0.000 | 12.477 | 16.820 | 0.000 |
| ln(Retail Area Ratio) | 0.085 | 38.670 | 0.000 | −0.062 | −33.320 | 0.000 |
| ln(Proportion of Residential Permit per Total Permit) | 0.027 | 9.000 | 0.000 | −0.083 | −29.590 | 0.000 |
| ln(Proportion of Commercial Permit per Total Permit) | 0.034 | 19.310 | 0.000 | 0.056 | 25.470 | 0.000 |
| ln(CPI-adjusted Local Tax per Households) | −0.293 | −54.240 | 0.000 | −0.434 | −10.680 | 0.000 |
| | | | | | | |
| Constant | 30.627 | 31.800 | 0.000 | 58.651 | 21.030 | 0.000 |
| Random Effects | | | | | | |
| ICC | 0.992 | | | 0.995 | | |
| Summary Statistics | | | | | | |
| Number of Parcel Observations (Level 1) | 85,124 | | | 41,302 | | |
| Number of Neighborhood Groups (Level 2) | 65 | | | 65 | | |

As with the non-residential model, distance to the nearest BRT stop had a significant and discernable effect on residential land prices, underscored by Figure 15. The figure shows residential land prices were generally higher for parcels within 300 meters of a bus stop than those beyond 300 meters, however the premium effect was noticeably bigger once median-lane BRT services were introduced. Prior to these services, residential values were slightly lower within 30 meters of the nearest bus stop, likely reflecting a nuisance effect, and then rose in the range of a 1.5% to 2.8% premium up to around 270 meters away. Following the BRT enhancements, premiums shot up significantly, eclipsing 10% up to 90 meters from the nearest bus stop. The absence of any nuisance effect within 30 meters of a BRT stop could very well reflect the high-amenity designs of Seoul's median-lane bus stops (see Figure 16) and perhaps even a different clientele who patronizes BRT than previous regular bus services. Beyond 60 meters, Figure 15 shows that the premium effects began to taper.

**Figure 15. Marginal Effects of BRT-Bus Stops by Distance Intervals**

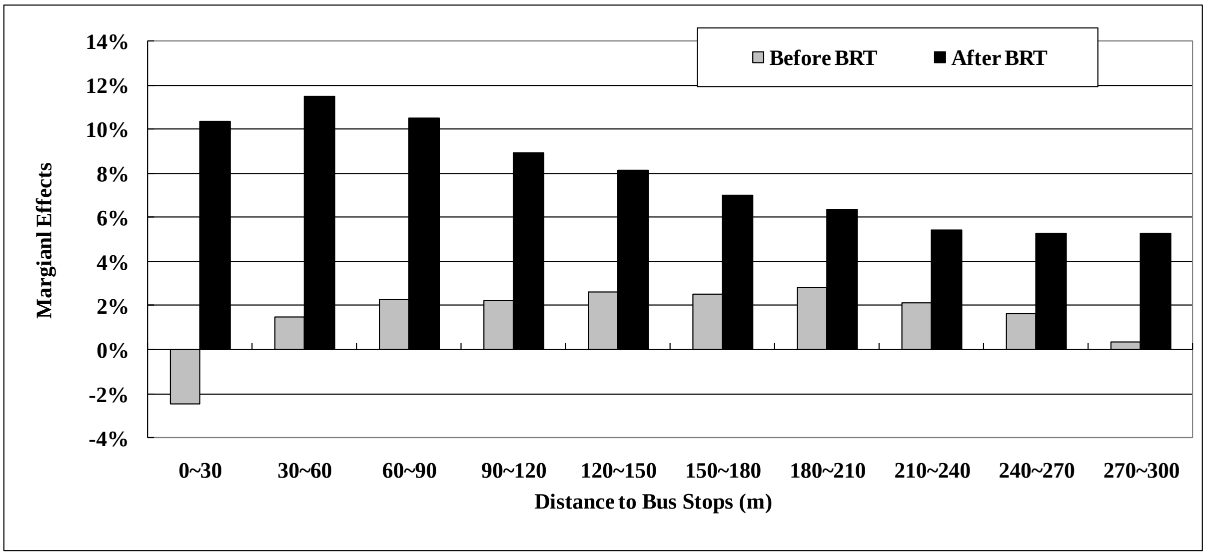



**Figure 16. Seoul's High-Amenity BRT Bus-Stop Infrastructure**

Photo: Seoul Metropolitan Government

The control variables in Table 7 generally align with expectations. Proximity to other infrastructure, including the CGC greenway, subways, and arterial roads were associated with higher residential land prices. Also, higher density residential parcels (e.g., row housing, multi-family housing, condominiums) were valued more than single-family residences (the suppressed dummy-variable category). Factors like high neighborhood densities, high park densities, and dense road networks also tended to increase residential land values. The signs on some variables in Table 7, however, are not easily interpretable and again could reflect unique, localized attributes of Seoul's real estate market.

## 7. Conclusion and Policy Implication

Our core research hypotheses were largely borne out by empirical results. Seoul's substantial upgrading of BRT services – in the form of adding over 70 kms of dedicated median-lane bus services in 2004 – nearly doubled bus operating speeds. In a crowded, congested, and land-constrained city like Seoul, increased accessibility prompted property owners and developers to intensify land uses along BRT corridors, mainly in the form of converting single-family residences to multi-family units, apartments, and mixed-use projects. Moreover, land markets capitalized these accessibility gains, particularly among parcels used for condominiums and higher density residential uses. Land price premiums in the 5 to 10 percent range were estimated for residences within 300 meters of BRT stops. For retail shops and other non-residential uses, impacts were more varied, ranging from 3 to 26 percent premiums over a smaller impact zone of 150 meters from the nearest BRT stop.

Our research results are consistent with those on rail-transit improvements. It is not transit "hardware" – i.e., steel-wheel trains or rubber-tire buses – that unleash land-use changes but rather the quality of service and more specifically, the comparative travel-time savings of taking transit vis-à-vis the private car. In Seoul, faster, more punctual bus services and the ease of transferring to subway portals triggered a market demand for higher density residential uses. Land-use intensification, along with the access improvements conferred by BRT, also translated into higher real-estate prices, especially for residential uses.

These research findings inform several possible policy responses. One, the desire to intensify land uses requires local planners to get ahead of the curve by changing zoning and regulatory restrictions governing densities and designs in advance of BRT enhancements. This, of course, assumes higher density development in BRT-served corridors is sought by planning agencies. Fortunately, this is most often the case since, after all, expensive transit investments require high ridership which a body of research has long shown requires high densities (Pushkarev and Zupan, 1977; Cervero, 1998). As the saying goes, “mass transit needs mass”. Zoning overlays, increases in permissible floor-area-ratio, and density bonuses are not the only programmatic changes that are needed in response to market pressures to intensify uses. Other supportive infrastructure, including water and sewerage trunk-line capacities, have to be upgraded and expanded to serve more households and businesses. Linking infrastructure like BRT to local zoning and land-use planning seems fairly straightforward, however it should be remembered that many cities in the developing work aiming to economize on transit investments by building BRT (e.g., Jakarta, Ankara, Cali, Abidjan) do not always have the institutional capacities and resources to carry out strategic land-use planning.

The presence of measurable land-value premiums conferred by BRT create revenue-generating opportunities as well, notably transit value capture. Since BRT is a public investment that yields benefits to private property owners, value capture aims to return a share of the value-added to public coffers to help finance the capital investment and subsequent operations. BRT-induced land appreciation can be partly recaptured through benefit assessment district financing and public-private joint development initiatives.

Presumably, all parties in joint development deals perceive benefits from intensifying development near transit – i.e., increased ridership for public operators and increased land prices and rents for private landholders – which eases the process of hammering out revenue-sharing agreements. Another implication of rising land prices, of course, is displacement of lower-income households and other potential mal-distributive effects. To redress such inequities, one possible use of revenues recaptured from benefitting property-owners is to underwrite the costs of providing affordable housing and shops to displaced residents and merchants.

It should be kept in mind that Seoul's BRT improvements did not occur in isolation. Rather they were part of a larger campaign to reclaim land given over to freeways and to enhance urban living as an alternative to exurban new-town development. No project epitomized this shift in urban policy more than the freeway-to-greenway conversion, Cheong Gye Cheon (CGC). Indeed, former mayor Myung-Bak Lee opted to upgrade the city's bus services and invest in dedicated-lane BRT partly to ensure high-quality transit was in place to absorb capacity lost and trips deflected by the CGC freeway demolition. In Seoul, BRT improvements were part of a larger policy agenda that required a systems approach. While our research focused on median-lane bus services, some of the estimated benefits were no doubt tied to other initiatives introduced at roughly the same time to improve mobility and quality-of-living in central Seoul. As is often the case, this one infrastructure component – BRT – was likely a necessary, though by itself, insufficient, factor in intensifying residential activities and increasing land values. Seoul's experiences underscore the importance of applying a systems approach to transit investments, tied to larger public purpose, which in the case of Seoul included re-generation and revitalization of the urban core.

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