Transport Policy 19 (2012) 85–92

Contents lists available at SciVerse ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Redistributive effects of bus rapid transit (BRT) on development patterns and property values in Seoul, Korea ☆

Myung-Jin Jun

Department of Urban Planning and Real Estate, Chung-Ang University, Korea

ARTICLE INFO

Available online 29 September 2011

Keywords:
Bus rapid transit (BRT)
Integrated urban model
Redistributive effects of BRT
Seoul
Random utility-based model
Land use-transport interaction

ABSTRACT

This study investigates the redistributive effects of Seoul's bus rapid transit (BRT) system on development patterns and property values using an urban simulation model. The Seoul Metropolitan Integrated Urban Model (SMIUM) combines the Seoul metropolitan input–output model with random utility-based location choice models and endogenous real estate markets.

The major findings of this study can be highlighted as follows. First, Seoul's BRT contributes to increased development density in urban centers, acting as a centripetal force to attract firms from the suburbs into urban cores and supporting arguments for Smart Growth proponents. Second, unlike its redistributive effects on nonresidential activities, the BRT has a limited effect on the redistribution of residential activities, implying that residential locations are less sensitive to accessibility improvements made by the BRT than are nonresidential locations. Third, reflecting the transferred space demands from the suburbs to the urban cores, the CBD reaps the highest property value gains, while all of the outer ring zones suffer from reduced property values.

1. Introduction

Investments in public transit play key roles in the implementation of Smart Growth strategies such as compact development and reductions in private vehicle usage. Proponents of Smart Growth argue that public transit reduces traffic congestion by shifting the travel mode from driving to transit, and that public transit leads to increases in development density, acting as a counterforce to urban sprawl. Among the different types of transit systems, Smart Growth emphasizes heavy and/or light rail transit systems because rail transit systems are markedly faster than conventional bus transit systems, providing noticeable accessibility benefits. Recently, the Bus Rapid Transit (BRT) method has become a popular alternative to rail transit systems due to its cost-effectiveness. As of 2005, there were approximately 70 BRT systems worldwide (Matsumoto, 2007).

Seoul introduced dedicated median-lane BRT services in 2004. An empirical survey showed that Seoul's BRT significantly increased bus speeds and contributed to an increase in bus ridership, providing substantial accessibility benefits along BRT corridors (Seoul Metropolitan Government, 2009). This study aims to investigate the redistributive effects of Seoul's BRT on development patterns and property values using an urban simulation model known as a Seoul Metropolitan Integrated Urban Model (the SMIUM) (Jun, in press-b), which combines the existing Seoul metropolitan input–output model (Jun, 2004, 2005, 2009, in press-a) with random utility-based location choice models and real estate markets.

This paper differs from prior research in terms of its study purpose and research methodology. Unlike existing studies, which have investigated the land use effects of the new transit system using statistical models and have focused on development in particular corridors or around station areas, this study examines the metropolitan-wide impacts of transit on development patterns, measuring the redistributive effects of the improved accessibility provided by the BRT. Previous studies have concluded that new transit investments typically redistribute growth within a metropolitan region rather than creating new growth, thus generating intra-regional transfers (TCRP, 1995; Handy, 2005). Therefore, the assessment of metropolitan-wide redistributive impacts of transit investments is warranted in terms of urban growth and property values.

This study also differs from previous research because it proposes a new analytical framework for estimating the effects of transit investments through the use of a random utility-based integrated urban model (Wegener, 2004). Conventional statistical models are limited to the accurate measurement of the metropolitan-wide redistributive effects of transit because it is difficult to separate the net effects of transit from other factors that affect land use and property values in metropolitan regions. However, an urban simulation model such as the SMIUM, which is based on the economic principles of utility maximization and is empirically calibrated, can

☆This Research was supported by the Chung-Ang University Research Grants in 2008.

E-mail address: mjjun1@cau.ac.kr

0967-070X/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tranpol.2011.09.003

measure the intra-regional redistributive effects of transit because the model can control all of the variables influencing development patterns and property values, except for the policy variable (i.e., accessibility improvements due to new transit investments).

This paper consists of four sections. The first reviews the existing literature, focusing on research dealing with the effects of public transit on land use and prices. The second section introduces Seoul's bus transit reforms and the BRT system. The third section describes the structure of the SMIUM and the operational version of the SMIUM model. The fourth section presents the effects of Seoul's BRT on development patterns and property values, followed by our conclusions and policy suggestions.

2. Literature review

Because this study aims to assess the redistributive effects of Seoul's BRT in terms of urban development and land prices, the literature review focuses on existing studies that have investigated the effects of public transit on development patterns and property values.

2.1. Research on the effects of transit on development patterns

Research on the effects of public transit on development patterns has focused predominantly on heavy and light rail systems. Theoretically, new transit systems affect land use patterns in two conflicting ways. Like a new highway investment, reduced travel time due to a new transit system may enable residents to live farther from the city center, contributing to sprawl. Conversely, a transit system might affect more dense development within transit corridors and at transit station areas because of improved accessibility to those areas, acting as a counterforce to continued sprawl (Handy, 2005).

Empirical research provides supportive evidence of high density development and increased property values along transit corridors and around station areas (Huang, 1996; Cervero and Landis, 1997; Cervero, 1997; Ryan, 1999). For example, Cervero and Landis (1997) examined the effects of the Bay Area Rapid Transit (BART) system in San Francisco, CA, USA in terms of land use and development impacts, concluding that "in a larger regional context, BART has played a fairly modest, though not inconsequential, role in shaping metropolitan growth in the San Francisco Bay Area. Its impacts have been highly localized and uneven, far from the uniform pattern of subcentering that planners had hoped for. Evidence suggests that BART has allowed downtown San Francisco to continue to grow and maintain its primacy in the urban hierarchy" (p. 331).

A considerable body of empirical research, however, suggests that public transit only minimally affects land use patterns without the proper real estate market conditions and public policies supporting high-density development (Knight and Trygg, 1977; Cervero, 1984; TCRP, 1995; Vesalli, 1996). After a comprehensive literature review, Handy (2005) concluded that the potential for transit to encourage higher densities depends on "the pace of growth in the region, existing land uses in station areas, the nature of the transit system, and public sector involvement. Without the right ingredients, increased densities are unlikely".

There are also contradictory studies on the effects of BRT on development patterns. For example, Levinson et al. (2002) argue that BRTs in Ottawa, Canada, Pittsburgh, PA, USA, Brisbane, Australia, and Curitiba, Brazil have had positive land use impacts, whereas Vuchic (2002) concluded that the development impacts of BRT were substantially lower than those of light-rail transit (LRT).

2.2. Research on the effects of transit on property values

Similar to studies of the effects of transit on development patterns, empirical research on the impacts of rail transit investment on land price has generated mixed results. Some empirical studies have provided supportive evidence showing significant land-price effects of rail transit: Bajic (1983) for the Spadina Corridor in Toronto, Canada; Voith (1991) for rail service in Philadelphia, PA, USA; Laakso (1992) for Helsinki, Finland; So et al. (1998) for Hong Kong; Landis for five California rail systems including BART, CalTrain, Sacramento Light Rail, San Diego Trolley, and the Santa Clara light rail (NHCRP, 1996); Knaap et al. (2001) for the light rail MAX system in Portland, OR, USA.

However, numerous studies have concluded that rail transit has no impact on land price. Cervero and Landis (1997) provided mixed results, arguing that no perceptible price effects were found in suburban residential properties along the San Francisco BART corridors; however, commercial properties in downtown San Francisco experienced very large value gains. Gatzlaff and Smith (1993) found no significant land-price impacts of the Miami, FL, USA Metrorail, and Bae et al. (2003) identified an anticipatory effect of Seoul's subway Line 5 but observed no price effects after the opening of the line.

A few empirical studies have investigated the property-value impacts of BRT. Cervero (2004) found small negative impacts on residential property values and small positive impacts on commercial property values in BRT corridors in Los Angeles, while Estupinan and Rodriguez (2008) found that properties near BRT bus stops in Bogota, Colombia gained significant land-value benefits with the creation of pedestrian-friendly environments around the bus stops. Most recently, Cervero and Kang (2009) investigated the effects of Seoul's BRT on land use and land values using multilevel binary logit models and hedonic price models. They found that parcels within 500 m of a stop (generally a five-minute walking distance) were more likely to experience more intensive use than were parcels more than 500 m from a BRT stop. They also documented residential land price premium increases of 5–10% within 300 m of BRT stops and non-residential (especially commercial use) land price premium increases of 3–26% within 150 m of stops.

Despite volumes of research and debates, the effects of transit on development patterns have not been settled. Previous studies have suggested that the effects of transit on development patterns and property values vary according to the nature of the transit system, the degree of accessibility improvement, economic conditions, the existing land use patterns of the region, and public sector involvement.

3. Seoul's bus transit system

Seoul has experienced remarkable urban development patterns. Known as one of the fastest growing cities in the world, Seoul's population has almost quintupled over the last half century, from 5.2 million in 1960 to 24.5 million in 2007. Thus, the core city of Seoul is one of most densely-populated urban areas in the world, with 16,500 residents per square kilometer. In addition, Seoul is noted for its fast suburbanization process. Massive suburban residential development including five new towns has attracted about 3.3 million people from the core city of Seoul to the suburbs over the last 20 years.

A rapid increase in car ownership due to increased per-capita income has contributed to the increased use of private vehicles, causing serious traffic congestion, especially along the major radial arteries linking the suburbs to the urban core. The Seoul Metropolitan Government considered the provision of a heavy-rail transit system as a policy option for resolving serious traffic congestion and introduced an 8-km rail transit system (subway) in 1974. Since then, Seoul's urban subway system has dramatically expanded to 487 km in 2004, with a daily ridership of more than 10 million.

Unlike the successful operation of the urban subway system, Seoul's bus transit system has been criticized because of its inconvenient, uncomfortable, and dangerous services (SDI, 2005). One of the bases for this criticism was its operation system. Seoul's bus services were operated by a few private bus companies, with no government controls over routes or schedules. Since there was no coordination among bus companies, many bus routes were circuitous, overlapping, and not adequately integrated with other transit services, such as subways (Pucher et al., 2005).

Faced with serious traffic congestion and citizen complaints, the Seoul Metropolitan Government introduced a wide range of reforms to its bus system in July 2004. The reforms included changes in the bus operation system, the fare system, and the bus route network system. The Seoul Metropolitan Government initially changed the bus operation system from a private to a 'semi-public' operation system, gaining control over bus routes, schedules, fares, and bus system design (SDI, 2005).

Subsequently, the flat fare system was changed to a distance-based fare system, and fares were modified to be based on the travel mode used. Thus, bus fare started at 800 Won (about US$0.65) for the first 10 km and increased by 100 Won for increments of 5 km. The bus fare also included up to four free transfers, applicable to both bus and subway systems (SDI, 2005). The incentive of free transfers substantially increased bus ridership. Moreover, a new smart card system was introduced to enhance ease of payment for travelers and to facilitate intermodal ridership.

One of the most marked changes in Seoul's bus system during this period of reform was the introduction of a new bus route network. The bus route network was entirely redesigned to integrate over 400 different bus routes in the metropolitan area. All of the bus services were grouped into four color-coded types. The blue buses operated at higher speeds and accessed median bus lanes, connecting suburban areas to downtown Seoul. The red buses were express buses designed especially for those commuting between downtown Seoul and satellite cities. The green buses were flexibly operated by private bus companies, connecting major subway stations and bus terminals outside of downtown Seoul. The yellow buses circled downtown Seoul and stopped at blue bus stops and major railway stations, as well as business, tourist, and shopping areas (SDI, 2005).

Lastly, a Bus Rapid Transit (BRT) network system was introduced that included exclusive median bus lanes, high-quality median bus stops, priority traffic signals at intersections, real-time information for passengers and system operators, and new, state-of-the-art buses (SDI, 2005). As shown in Fig. 1, as of 2008, there were 81 km of BRT network over seven different corridors.

The Seoul Metropolitan Government (2009) reported that BRT has contributed to significant increases in bus ridership and commute speed. Bus passengers have increased by 22%, from 3.82 million per day in early 2004 (before BRT services) to 4.67 million per day by the end of 2008. Prior to bus system reform, subways carried almost one million more passengers per day then did buses; however, in 2009, the bus system carried more than 100,000 more daily passengers than did the subway system.

The implementation of exclusive median bus lanes has substantially improved bus speeds. As shown in Fig. 2, the average bus speed doubled in the Dobong–Mia BRT corridor (from 11 to 22 km/h) and increased by 64% and 33% in the other two major BRT corridors between June 2004 and December 2004 (Seoul Development Institute, 2005). Because of a mode shift from automobiles to public transit and the removal of buses from general traffic to dedicated median lanes, car speeds also increased in these BRT corridors.

4. Research methodology

This study uses an urban simulation model (the SMIUM) to estimate the redistributive impacts of Seoul's BRT in terms of residential and nonresidential development, and property values. The SMIUM has three location choice modules: production,

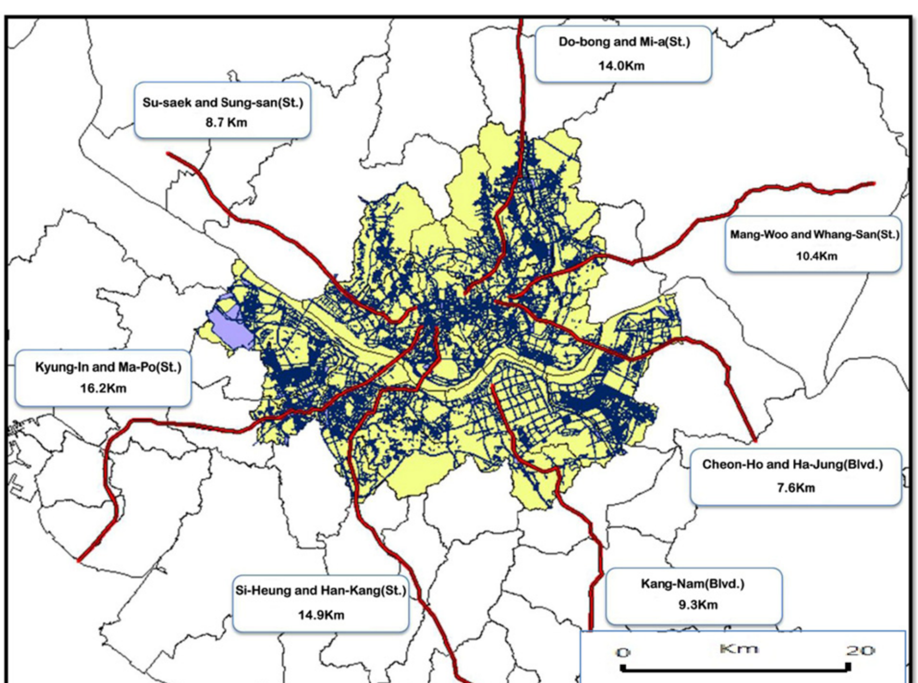

Fig. 1. Seoul's BRT routes.

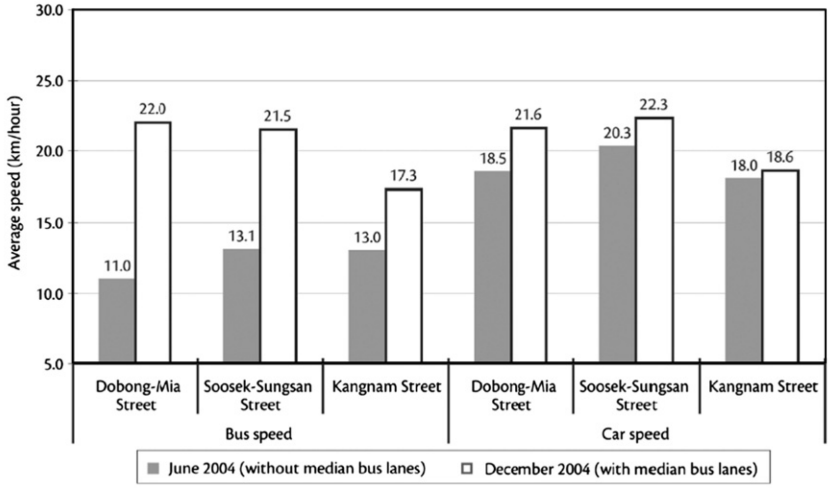

Fig. 2. Average bus and car speeds before and after the implementation of exclusive median bus lanes.
Source: Seoul Metropolitan Government (2009).

residential, and shopping locations. The production location choice module determines the production (employment) location by sector and estimates trade flow using random utility concepts, provided exogenous final demands according to sector and zone. The residential location choice module uses random utility theory to determine residential locations by income, while the shopping location choice module determines the locations of household consumption by income. In addition, the real estate market component of the SMIUM estimates floor space demand and monthly rents for residential and non-residential spaces (Jun, in press-b).

The SMIUM has three deterministic utility functions to choose between production, residence, and shopping locations. The utility function of production location choice consists of production and transportation costs, while that of residential location choice includes residential attractiveness measures such as amenities, school quality, residential land price, and commuting costs. The utility function of shopping location choice consists of shopping attractiveness and transportation costs.

A variety of data sets were collected from numerous sources in order to construct the empirical model of the SMIUM (for more detailed explanations of the empirical model building process, please refer to Jun, in press-b). The primary data sources were the 2003 interregional Input–Output Transaction Table (Bank of Korea, 2007) and the 2006 Household Travel Survey for the Seoul Metropolitan Area (SMA). Employment and household data came from the 2003 Korea Statistical Office (KSO), while travel statistics were derived from the 2006 Household Travel Survey. The travel time SKIM data were taken from the 2001 transportation network data for the SMA.

The SMIUM consists of ten industrial sectors: three household income groups (high, medium, and low), two housing types (single and multiple), 23 land use zones (LUZ) (see Table A1 and Fig. A1), and three land use types (residential, industrial, and commercial). Since the SMIUM is a constrained nonlinear model, GAMS CONOPT Solver was used to determine the optimal solutions for the nonlinear equations. The equation system of the SMIUM includes 17,664 equations and 17,664 variables: 5,290 equations for the production location choice module ($10 \times 23 \times 23$), 1,587 equations for the residential location choice module ($3 \times 23 \times 23$), 1,587 equations for the shopping location choice module ($3 \times 23 \times 23$), and 9,200 equations for computing deterministic utility, land demand, rent, and internal data conversions, such as categorizing workers based on occupation into households according to income group (Jun, in press-b).

For model validation, Jun, in press-b compared the estimated and actual values of employment, household, and rent according to zone. The estimated results from the SMIUM accurately represented actual values in terms of jobs and households, as well as rent by land use type, with an average 2% discrepancy, thus demonstrating the high validity of the SMIUM (see Tables A2 and A3 for model validation results).

5. Impacts of Seoul's BRT on land use and rent

Gauging the effects of BRT on development patterns and rent requires several steps. The first task was to obtain baseline SKIM matrices (travel time and distance) for the SMIUM. Initially, we obtained baseline SKIMs that were derived after trip assignments using the SMAs network with 1132 transportation analysis zones (TAZ), 22,049 links and 7,292 nodes from the Gyunggi Research Institute (GRI). Since the SMIUM and transportation model have different zone systems, we overlaid the LUZ map on the TAZ map to select 23 TAZs comprising the centroids of LUZs and constructed two 23x23 baseline SKIM matrices (travel time and distance). The baseline travel time SKIM was fed into the SMIUM for the baseline run, which represents the no-BRT scenario.

The next task was to create a new 23x23 travel time SKIM matrix that accounts for the improved travel speeds of the BRT. This study revised baseline SKIM data from the Seoul Metropolitan Government (2009) that were based on travel time savings for BRT corridors. Several steps were taken in order to create a new SKIM for the BRT scenario: (1) select all LUZs with BRT stops, (2) determine zone-to-zone network distances from the baseline distance SKIMs for the selected LUZs, (3) calculate the ratios of BRT length to total zone-to-zone distance, and (4) revise baseline travel time SKIMs based on improved travel speeds for the BRT portions while using baseline travel times for the non-BRT portions.

Below, we present the process for deriving new SKIMs using an example. Three LUZs (zones 1, 2, and 19) through which the Goyang–Ilsan BRT route passes were selected. According to the baseline distance SKIM, the network lengths between zone 1 and 2 and between zone 1 and 19 are 4.1 and 26.8 km, respectively. Since the length of the Goyang–Ilsan BRT route starting from zone 1 is 8.7 km, a bus rider traveling from zone 1–2 or vice versa can enjoy travel time savings due to the improved travel speed of the BRT because the BRT route travels beyond zone 2. However, a bus rider moving from zone 1 to zone 19 enjoys time savings only for the BRT segments, which cover only one-third of the total travel length (8.7/26.8 Km). We substitute the improved travel speeds into the BRT segments to compute a new travel time between zone 1 and 19 under the with-BRT scenario. All of the BRT-related zone-to-zone travel times in the baseline time SKIM were revised under the same principle.

The third task was to execute the SMIUM with and without (baseline) the BRT. The scenario with BRT used the revised SKIM, using all of the other same input data as in the baseline run. Since we aimed to estimate the redistributive impacts of the BRT with respect to residential and nonresidential development patterns and property values, we assumed that BRT investment generated no new growth for the region. In other words, we assumed a closed city model with fixed total household and employment for Seoul, regardless of BRT investment. The SMIUM generated information regarding employment by zone and sector, households by zone and income, and monthly rents for residential and non-residential spaces by zone.

5.1. The redistributive effects of BRT on development patterns

Table 1 shows the effects of the BRT on employment location. The employment statistics determined by LUZ were aggregated into zone types, as defined in Table 1. There were three interesting findings. First, the BRT was likely to contribute to the relocation of firms from suburban areas into the core city of Seoul, acting as a counterforce to employment suburbanization. The city of Seoul attracts approximately 57,000 jobs from the suburbs. Second, almost 90% of total job growth within the core city due to the BRT was centralized in the CBD and subcenters, implying that the BRT contributes to the gravitation of firms to urban centers. Third, the outer ring suburb zones were most negatively impacted, losing almost 50,000 jobs, while the inner ring zones experienced modest job losses of less than 10,000.

As shown in Table 2, the distributive effects of the BRT on residential development patterns were different from its effects on employment distribution. The redistributive effects of the BRT on households were significantly smaller than its effects on employment, indicating that residential location is less sensitive to accessibility improvements than is firm location. Similar to employment location, the BRT contributed to population growth in the core city, whereas suburban areas decreased in population. However, within the central city, the effects on household distribution were different from the effects on jobs. Unlike job relocations into the CBD and subcenters, non-center zones experienced the largest household gains, with the addition of approximately 5,000 households, possibly due to the network effects of the BRT. Inner ring zones experienced modest household gains, with the addition of 2600 more households. Finally, outer ring zones experienced the greatest household losses because the BRT was not available in those zones.

Table 1
Changes in employment by zone type with and without the BRT.

Area	Zone type	Without BRT (A)	With BRT (B)	Change (B–A)
Central Seoul	CBD	620,305	651,885	31,580
	Subcenter	1,652,259	1,671,869	19,610
	Rest of Seoul	1,565,295	1,571,303	6,008
	Subtotal	3,837,859	3,895,057	57,198
Suburbs	Subcenter	92,362	92,762	400
	Inner ring	1,776,811	1,767,512	−9,299
	Outer ring	1,690,466	1,642,167	−48,299
	Subtotal	3,559,639	3,502,441	−57,198

Table 2
Changes in household number by zone type with and without the BRT.

Area	Zone type	Without BRT (A)	With BRT (B)	Change (B–A)
Central Seoul	CBD	96,766	98,579	1,813
	Subcenter	1,027,028	1,030,371	3,342
	Rest of Seoul	2,121,223	2,125,825	4,603
	Subtotal	3,245,017	3,254,775	9,758
Suburbs	Subcenter	54,934	55,094	160
	Inner ring	2,151,337	2,154,012	2,675
	Outer ring	1,946,210	1,933,617	−12,593
	Subtotal	4,152,481	4,142,723	−9,758

5.2. The effects of BRT on residential and non-residential rents

Table 3 presents changes in monthly rent according to land use type after the introduction of BRT. Changes in rent were predicted to remain consistent with changes in jobs and households because the SMIUM determines rents endogenously according to space demand assuming a fixed space supply. Overall, the BRT did not significantly affect rent, changing monthly rent per m^2 by an average of only US$1.00, regardless of the space type. An exception was the nonresidential rent in the CBD (Zone 1), where commercial and industrial monthly rents increased by US$3.50 and US $2.70, respectively, indicating greater demand for non-residential space. Residential rent also increased in the CBD, but the rental impact of the BRT was relatively minor, illustrating an increase of only US$0.60 per m^2.

Reflecting the transfer of housing demands from outer ring zones in the suburbs to the central city and inner ring zones, most zones in the city of Seoul increased in value due to the presence of the BRT, while the outer ring zones decreased in value. Some inner ring zones such as Guri, Kacheon, and Suwon experienced rental gains, indicating that those zones were beneficiaries of the BRT.

Table 3
Changes in monthly rent by land use type after the introduction of BRT. (Unit: US$/$m^2$).

Zone name	Industrial space	Commercial space	Residential space
City of Seoul			
Jongrogu/Junggu	2.7	3.5	0.6
Yongsan/Mapo/Seodemun/Unpyung	0.3	0.1	0.1
Sungbuk/Kangbuk/Dobong/Nowon	0.0	−0.1	0.0
Dongdemun/Jungrang/Sungdong/Kwangjin/Kangdong	0.0	0.6	0.2
Songpa/Kangnam/Seocho	0.4	0.3	0.1
Dongjak/Kwanak/Kumcheon	0.1	−0.1	0.1
Youngdungpo/Guro/Yangcheon/Kangseo	0.4	0.6	0.2
Kyunggi Province			
Yujungbu/Yangju/Dongducheon	−0.1	0.0	0.0
Pocheon/Yuncheon	−0.1	−0.7	0.0
Guri/Namyangju/Hanam	0.1	1.5	0.3
Gapyung/Yangpyung	−0.2	−0.7	−0.1
Sungnam/Bundang	−0.3	−0.2	0.0
Kwangju/Yeoju/Icheon	−0.1	−0.7	−0.1
Kacheon/Yewang/Gunpo/Anyang	0.1	0.3	0.2
Suwon	0.0	0.2	0.1
Yongin/Ansung	−0.2	−0.8	−0.1
Hwasung/Osan/Pyungtek	−0.2	−0.7	−0.1
Kwangmyung/Sihung/Ansan	−0.3	−0.9	−0.1
Goyang/Paju/Kimpo	−0.2	−0.3	0.0
Bucheon	−0.1	−0.1	0.0
City of Incheon			
Junggu/Donggu	−0.1	0.2	0.1
Seogu/Keyang/Bupyung/Kanghwa	−0.2	−0.9	−0.1
Namgu/Yunsu/Namdong/Ongjin	−0.3	−0.8	−0.1

6. Conclusions

This study investigated the redistributive effects of Seoul's BRT on development patterns and rent. Our simulation results yielded several interesting findings. First, Seoul's BRT is likely to act as a centripetal force, attracting firms to the central city from the suburbs by strengthening the abilities of activity centers to attract economic activities. However, the BRT has limited effects on residential activities, implying that accessibility benefits due to the BRT are not sufficient to generate significant changes in residential location. These findings support the findings of Cervero and Landis (1997), who concluded that San Francisco's BART system contributed to increased commercial activities downtown, with no perceptible impacts on residential settings in the suburbs. Second, Seoul's CBD is expected to experience the greatest gains in commercial and industrial rents, with relatively small increases in residential rents; however, the outer ring zones in the suburbs are predicted to experience rent declines in both residential and nonresidential spaces.

These findings suggest several policy implications. First, since Seoul's BRT has contributed to increased bus ridership, reduction of traffic congestion in the BRT corridors, and increased development density in the urban centers, therefore serving as a counterforce to urban sprawl, these findings support arguments made by

Table A1
Land use zones (LUZ) for the SMIUM.

City or Province	ID	Zone	Zonal characteristic
City of Seoul	1	Jongrogu/Junggu	CBD
	2	Yongsan/Mapo/Seodemun/Unpyung	Non-center
	3	Sungbuk/Kangbuk/Dobong/Nowon	Non-center
	4	Dongdemun/Jungrang/Sungdong/Kwangjin/Kangdong	Non-center
	5	Songpa/Kangnam/Seocho	Subcenter
	6	Dongjak/Kwanak/Kumcheon	Non-center
	7	Youngdungpo/Guro/Yangcheon/Kangseo	Subcenter
Gyunggi Province	8	Yujungbu/Yangju/Dongducheon	Inner ring
	9	Pocheon/Yuncheon	Outer ring
	10	Guri/Namyangju/Hanam	Inner ring
	11	Gapyung/Yangpyung	Outer ring
	12	Sungnam/Bundang	Inner ring
	13	Kwangju/Yeoju/Icheon	Outer ring
	14	Kacheon/Yewang/Gunpo/Anyang	Inner ring
	15	Suwon	Inner ring
	16	Yongin/Ansung	Outer ring
	17	Hwasung/Osan/Pyungtek	Outer ring
	18	Kwangmyung/Sihung/Ansan	Inner ring
	19	Goyang/Paju/Kimpo	Outer ring
	20	Bucheon	Inner ring
City of Incheon	21	Junggu/Donggu	Subcenter
	22	Seogu/Keyang/Bupyung/Kanghwa	Outer ring
	23	Namgu/Yunsu/Namdong/Ongjin	Outer ring

Table A2
Differences between observed and estimated employment and households.

City or Province	Zone name	Employment	Household
City of Seoul	Jongrogu/Junggu	103.70%	100.40%
	Yongsan/Mapo/Seodemun/Unpyung	100.50%	100.80%
	Sungbuk/Kangbuk/Dobong/Nowon	99.40%	101.80%
	Dongdemun/Jungrang/Sungdong/Kwangjin/Kangdong	99.90%	100.80%
	Songpa/Kangnam/Seocho	100.90%	93.90%
	Dongjak/Kwanak/Kumcheon	101.80%	101.60%
	Youngdungpo/Guro/Yangcheon/Kangseo	101.50%	100.10%
Gyunggi Province	Yujungbu/Yangju/Dongducheon	99.40%	101.70%
	Pocheon/Yuncheon	100.00%	101.60%
	Guri/Namyangju/Hanam	99.50%	102.30%
	Gapyung/Yangpyung	99.20%	101.90%
	Sungnam/Bundang	101.20%	102.20%
	Kwangju/Yeoju/Icheon	99.90%	101.60%
	Kacheon/Yewang/Gunpo/Anyang	101.20%	101.70%
	Suwon	99.90%	101.60%
	Yongin/Ansung	99.40%	101.70%
	Hwasung/Osan/Pyungtek	99.40%	101.50%
	Kwangmyung/Sihung/Ansan	99.30%	101.50%
	Goyang/Paju/Kimpo	99.30%	101.50%
	Bucheon	99.80%	102.00%
City of Incheon	Junggu/Donggu	101.20%	101.80%
	Seogu/Keyang/Bupyung/Kanghwa	100.00%	101.50%
	Namgu/Yunsu/Namdong/Ongjin	100.30%	101.50%

Smart Growth proponents. There are three important factors that may determine the positive development impacts of Seoul's BRT: Seoul's spatial characteristics, Seoul's integrated bus and subway network, and local government policies.

Seoul's spatial structure can be characterized by compact development and multi-centric urban form (Jun, 1995). Strong gravitation toward urban centers and compact development enables high bus ridership and increases downtown nonresidential development. Other important factors are the integration of bus and subway networks and monetary incentives for modal transfers. These factors play important roles in the shift from private vehicle use to public transit, therefore contributing to increasing bus ridership. As argued by Cervero and Kang (2009), the Seoul Metropolitan Government played a critical role in the success of the BRT project because its construction was part of a massive urban renewal project, the Cheong Gye Cheon Restoration Project, which demolished surface streets, elevated highways and restored previously-existing waterways to downtown Seoul. The local government took a system-wide approach and provided full financial and administrative support to ensure that the BRT was able to compensate for losses in commuter capacity and rerouted traffic due to this freeway demolition.

Although this study supports the argument that the BRT strengthened gravitation toward urban centers, interpretations of these findings requires caution. Since the SMIUM distributes population and employment under market-clearing conditions without considering dynamic aspects of the urban system, the redistribution effects of the BRT presented in this study have not yet been observed. Time is required for the redistribution effects to be realized, but it is impossible to predict when such redistribution effects will occur due to our model's limitations.

Indeed, factors such as real estate market conditions and government interventions in the land market may preclude the realization of redistributive effects. For example, since Seoul is notable for strict land use regulations, such as the requirements for Greenbelt preservation, positive impacts of the BRT might be offset by land use regulations such as building height caps, floor space ratio controls, and industrial and commercial land use regulations. Regulations hindering the economic vitality of downtown Seoul must be removed in order to fully capture the benefits provided by the introduction of a BRT.

Appendix A

See Tables A1–A3 and Fig. A1 here.

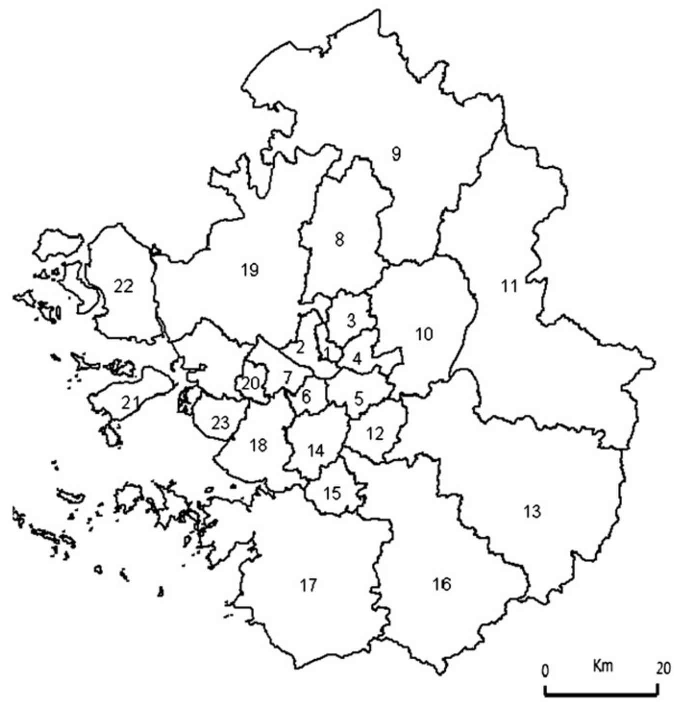

Fig. A1. Geographical boundaries of the 23 land use analysis zones.

Table A3
Differences between observed and estimated monthly rents by space type.

City or Province	Zone name	Industrial space	Commercial space	Residential space
City of Seoul	Jongrogu/Junggu	99.20%	99.30%	102.00%
	Yongsan/Mapo/Seodemun/Unpyung	100.10%	99.80%	98.80%
	Sungbuk/Kangbuk/Dobong/Nowon	99.90%	100.30%	100.70%
	Dongdemun/Jungrang/Sungdong/Kwangjin/Kangdong	99.90%	99.90%	98.80%
	Songpa/Kangnam/Seocho	100.50%	99.70%	94.50%
	Dongjak/Kwanak/Kumcheon	99.90%	99.30%	100.20%
	Youngdungpo/Guro/Yangcheon/Kangseo	100.00%	99.40%	97.90%
Gyunggi Province	Yujungbu/Yangju/Dongducheon	99.90%	100.30%	100.80%
	Pocheon/Yuncheon	100.20%	100.10%	101.00%
	Guri/Namyangju/Hanam	100.00%	100.10%	101.70%
	Gapyung/Yangpyung	100.00%	100.50%	102.20%
	Sungnam/Bundang	99.90%	99.50%	100.70%
	Kwangju/Yeoju/Icheon	100.20%	100.10%	100.40%
	Kacheon/Yewang/Gunpo/Anyang	100.00%	99.30%	100.20%
	Suwon	100.00%	100.00%	100.30%
	Yongin/Ansung	99.90%	100.30%	100.70%
	Hwasung/Osan/Pyungtek	100.10%	100.40%	99.90%
	Kwangmyung/Sihung/Ansan	100.00%	100.40%	99.90%
	Goyang/Paju/Kimpo	99.90%	100.40%	100.00%
	Bucheon	99.90%	100.10%	101.20%
City of Incheon	Junggu/Donggu	100.00%	99.40%	101.10%
	Seogu/Keyang/Bupyung/Kanghwa	100.30%	100.00%	100.20%
	Namgu/Yunsu/Namdong/Ongjin	99.90%	99.80%	100.10%

References

Bae, C.-H., Jun, M.-J., Park, H., 2003. The impact of Seoul's subway line 5 on residential property values. Transport Policy 10, 85–94.

Bank of Korea, 2007. Multi-Regional Input–Output Table of 2003, available at: 〈http://ecos.bok.or.kr/〉.

Bajic, V., 1983. The effects of a new subway line on housing prices in metropolitan Toronto. Urban Studies 20, 147–158.

Cervero, Robert, 1984. Light rail transit and urban development. Journal of the American Planning Association 50 (2), 133–147.

Cervero, R., 2004. The property value case for transit. In: Dunphy, R., et al. (Eds.), Developing Around Transit: Strategies and Solutions that Work, Urban Land Institute, Washington, D.C.

Cervero, R., 1997. Transit-Induced Accessibility and Agglomeration Benefits: A Land Market Evaluation. Berkeley: Institute of Urban and Regional Development, Working Paper 691.

Cervero, R., Landis, J., 1997. Twenty years of the bay area rapid transit system: land use and development impacts. Transportation Research Part A 31 (4), 309–333.

Cervero, Robert, Kang Chang Deok, 2009. Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea. UCB-ITS-VWP-2009-4 UC Berkeley Center for Future Urban Transport: Institute of Transportation Studies, UC Berkeley.

Estupinan, N., Rodriguez, D., 2008. The Relationship between urban form and station boardings for Bogotá's BRT. Transportation Research Part A 42, 296–306.

Gatzlaff, D.H., Smith, M.T., 1993. The impact of the Miami Metrorail on the value of residences near station locations. Land Economics 69 (1), 54–66.

Handy, S., 2005. Smart growth and the transportation-land use connection: what does the research tell us? International Regional Science Review 28 (2), 1–22.

Huang, H., 1996. The land-use impacts of urban rail transit systems. Journal of Planning Literature 11, 17.

Jun, M.J., 1995. Is Seoul really polycentric? Journal of Korea Planning Association 30, 285–294.

Jun, M.J., 2004. A Metropolitan Input–output model: multisectoral and multispatial relations of production, income formation, and consumption. Annals of Regional Science 38, 131–147.

Jun, M.J., 2005. Forecasting urban land use demand using a metropolitan input–output model. Environment and Planning A 37, 1311–1328.

Jun, M.J., 2009. The economic effects of Seoul's job decentralization: a metropolitan input–output analysis. Journal of Regional Science 49 (2), 311–327.

Jun, M.J. The economic costs and transportation benefits of Seoul s industrial land use controls. Urban Studies. doi:10.1177/0042098011419235. In press-a.

Jun, M.J. The effects of Seoul's greenbelt on the spatial distribution of population and employment, and on the real estate market. Annals of Regional Science. doi:10.1007/s00168-011-0461-5. In press-b.

Knaap, G.J., Ding, C., Hopkins, L.D., 2001. Do plans matter? The effects of light rail plans on land values in station areas. Journal of Planning Education and Research 21 (1), 32–39.

Knight, L.Robert, Trygg, Lisa L., 1977. Evidence of land use impacts of rapid transit systems. Transportation 6, 23–247.

Laakso, S., 1992. Public transportation investment and residential property values in Helsinki. Scandinavian Housing and Planning Research 9, 217–229.

Levinson, H., Zimmerman, S., Clinger, J., Rutherford, S., 2002. Bus rapid transit: an overview. Journal of Public Transportation 5 (2), 1–30.

Matsumoto, Naoka, 2007. Analysis of Policy Processes to Introduce Bus Rapid Transit Systems in Asian Cities from the Perspective of Lesson-drawing. In: Air Pollution Control in the Transportation Sector: Third Phase Research Report of the Urban Environmental Management Project, Chapter IV.7. pp. 351–376, IGES (Hayama).

National Cooperative Highway Research Program, 1996. Integration of Land use Planning with Multimodal Transportation Planning. Draft Interim Report. NCHRP 8 32 (3).

Pucher, John, Park, Hyngyong, Kim, Mook Han, Song, Jumin, 2005. Public transport reforms in Seoul: innovations motivated by funding crisis. Journal of Public Transportation 8 (5), 41–62.

Ryan, S., 1999. property values and transportation facilities: finding the transportation-land use connection. Journal of Planning Literature 13 (4), 412–427.

Seoul Development Institute, 2005. Toward Better Public Transport. Seoul Development Institute, Seoul Metropolitan Government, Seoul, Korea.

Seoul Metropolitan Government, 2009. Achievement and Present State of Public Transit Reform in Seoul, 2009. Seoul Metropolitan Government, Seoul.

So, H.M., Tse, R.Y.C., Ganesan, S., 1998. Estimating the influence of transport on house price: evidence from Hong Kong. Journal of Property Valuation and Investment.

Transit Cooperative Research Program (TCRP), 1995. An Evaluation of the Relationships Between Transit and Urban Form, Research Results Digest, No. 7, June.

Vesalli, Kaveh V., 1996. Land use impacts of rapid transit: a review of the empirical literature. Berkeley Planning Journal 11, 71–105.

Voith, R., 1991. Transportation, sorting, and house values. Journal of the American Real Estate and Urban Economics Association 19, 117–137.

Vuchic, V., 2002. Bus semirapid transit model development and evaluation. Journal of Public Transportation 5 (2), 71–96.

Wegener, M., 2004. Overview of land-use transport models. In: Hensher, D.A., Button, K. (Eds.), Transport Geography and Spatial Systems, Pergamon/Elsevier Science, Kidlington, UK, pp. 127–146.