Green Belt Policy Change and Uninvited Aftereffect in Seoul

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Abstract:

Urban Dynamics (UD) modeling as a derivative approach of System Dynamics is useful in measuring the various impacts originating from the dynamic interrelationship between urban subsystems and proposed urban policies. This research revisits the basic premises defined by existing UD documents and examines the feasibility of alternative UD models. As a specific example, this research focuses on behavioral changes of urban dynamics if the Green Belt areas in Seoul and the Capital Region as a whole are readjusted. The measurements are based upon a series of simulation works on the urban system, going beyond the traditional triplicate set of population, housing, and business activities. This research estimates that the removal of Green Belt control would definitely exert a significant impact on the urban dynamics of Seoul. The government-initiated Green Belt cancellation, however, would rather decrease the population size of Seoul and at the same time result in deterioration of overall quality of life (QOL) in the long-run as both Seoul and the Capital Region are interconnected by causal loops. Sensitivity analysis suggests, among others, that Seoul may lose 1.5 million or more people while the rest of the Capital Region would have to accommodate most of the out-migrated Seoul population over the next three decades. Judging from these research findings, this paper recommends that key stakeholders, including both citizens and policy makers, should decide how to deal with the major trade-off questions on the urban policy agenda.

Key Words: Green Belt, Seoul and the Capital Region, urban dynamics

I. Introduction

Traditional Urban Dynamics (UD), as a derivation of System Dynamics (SD), has illustrated the social and business forces in the growth and stagnation of cities, primarily in the United States (Forrester 1969, Mass 1974, Schroeder et. al. 1975, Alfeld and Graham 1976, Forrester 1992, Alfeld 1995). Among these, extending Forrester's original concepts of 1969, Alfeld and Graham (1976) introduce the Urban2 Model to explain the evolution of an urban system.[1] Non-US case studies include Shimada, et. al. (1986), Santos (1996), Sancar and Onaran (1997), Saeed (1998), Kim, Moon, and

Kim (1999), Wolfeden (1999), Ness and Low (2000), Moon (2000, 2002), Hong, et. al. (2000), Choi (2003), and Lee and Lee (2004).[2]

The ideological implication that growth 'makes jobs,' suggested by Molotch (1976), is shared by the UD approaches. They all identify growth as the central concern in urban politics, but the UD approaches remind us that any type of growth has double-edged characteristics. In fact, the UD models reiterate the notion that an urban system is fundamentally constrained by some fixed limitations on resources that can affect growth throughout time.

Accepting the UD methods, negative counterbalances are not necessarily unexpected events forcefully blindly by the system and accepted indiscriminately. It is required that stakeholders decide which trade-offs they prefer and which amenities they wish to forego in the process of gaining others. In other words, every city can improve the well-being of its own residents and regulate its attractiveness to outside migrants by selectively focusing upon the internal trade-offs that its residents prefer (Alfeld and Meadows 1974).

Recounting personal experiences in Lowell, Boston, Concord, and Marlborough (all in Massachusetts) and Palm Coast (in Florida), Alfeld (1995) explains that UD suffers from two shortcomings—limited detail and limited resources. The former refers to the model's apparent inability to directly touch upon the everyday administrative decisions that determine a city's fate. The latter refers to the larger national (and global) setting, of which UD is only a part. Richardson (1996) also sets out a personal list of 'system dynamics problems,' including issues in the enhancement of technical and interpretive aspects of modeling, in addition to the advancement and propagation of good practice.

Judging from these recommendations, the best UD strategy is geared toward not devising too narrow and thus too specific diagnosis and prescription against controversial urban problems, as this may easily distort the intrinsic nature of the urban dynamics. Therefore, ahead of suggesting any alternative model, UD modelers have to concentrate on the two basic but still controversial criteria of efficiency and equity, both of which are mutually exclusive or at least separable or complementary in the process of model building.[3] Secondly, the necessary and sufficient conditions to properly manage the urban dynamics should be given to the premise that explicit urban policies should consistently dominate other non-urban (implicit) policies (Lim 1988).[4] Otherwise, urban problems could be more arbitrarily and inconsistently manipulated or simply run out of control as pre-designed goals would usually lead to unanticipated impacts on other spheres.

Following the above survey of UD literature to identify the critical issues raised by researchers, we present a brief overview of the history of Korean Green Belt policies. With this background setting, we proceed with Green Belt UD modeling and simulation works. In specific, we focus on the formation of causal loops and the experiment with stock-flow diagrams ascribed to the relaxation of Green Belt systems in Seoul and the Capital Region as a whole. We also include the gains and losses of the new Green Belt move, synthesizing the dichotomized opinions between anti- and pro-Green Belt campaigners. From a series of analyses and simulations, we derive important strategic policy leverages. We close this paper with a discussion of how to deal with the major trade-off questions on the urban policy agenda.

Ⅱ. Korean Green Belt Policies: Gains and Losses

1. General Information

The Korean Green Belt (GB) regulations, first introduced in 1971, have been regarded as the strictest measure to discourage the sprawl of Seoul and the Capital Region at large,[5] fundamentally safeguarding land for agriculture and recreation. They were also applied in 13 other large or medium-sized cities in Korea, covering a total of 5,397Km^2.

Without any appropriate compensation countermeasures, the law prohibits landowners within the Green Belt areas from changing existing land uses for purposes other than agriculture, which includes expansion or renovation of existing residential units. In principle, GB conversion approval should not be given except in a handful of cases confined to public uses, such as military purposes and road expansion. Since its inception, however, with various reasons and excuses, the Green Belt regulations per se have been relaxed more than 50 times, without any boundary readjustment.

2. Genealogy of Korean Green Belt Policies

In Korea, the Green Belt regulations of 1971 were devised as the ultimate means of curbing urban sprawl. Borrowing SD or UD terminology, it seems like a pulse or a shock changing the direction of the flow itself, which in turn would transform the volume of stock. The immediate aim was given to preservation of the Green Belt areas, almost stopping the expansion of the urbanized areas.

Upon the announcement of the Green Belt regulations, the strongest objection naturally came from the aboriginal land owners as their land uses were restricted to solely agricultural purposes, which would render land relatively cheap compared to that of the non-Green Belt areas, Furthermore, they were furious because of the arbitrariness in the decision-making and implementation processes. Even though their voice was not strong enough to achieve the boundary amendment of the Green Belt regulations under the authoritarian quasi-military regime throughout the 1970s and 1980s, it has become louder and louder as Korea has transformed into a more democratic society.

In addition, the ever-growing numbers who have purchased land within the Green Belt areas seem to have joined the argumentative voices of the remaining aboriginal owners, as a high portion of the former are believed to seek potential speculative interest from the property transaction. Even though they do not have the de jure title to request the abolition of the Green Belt regulations, they would gain windfalls if the regulations were lifted. Confronted with various complaints, the Korean government has continually taken administratively inexpensive and convenient options—adopting a series of corrective measures, which would incrementally relax the legal standards of the Green Belt areas.

The Green Belt system has definitely contributed to the prevention of city expansion and indiscriminate development, as well as the protection of the environment and quality of life (see Table 1). Concurrently, it has also incurred significant impact on the land in the inner and outer rings of Green Belt areas. As the supply of usable land has become constrained, especially around the metropolitan area, the anti-Green Belt campaigners insist, the land price as a whole, already worsened by rapid urbanization, has skyrocketed in a short span. The anti-Green Belt activists have repeated that the Green Belt areas should be reframed to facilitate business activities in the era of ‘globalization.’[6]

Table 1. Land Use Patterns of Seoul and Its Green Belt Areas in 1999

Seoul		Seoul Green Belt Areas	
Residential	191.4Km^2(31.6%)	Forest	99.9Km^2(59.9%)
Green Belt	166.8Km^2(27.5%)	Road	35.9Km^2(21.5%)
Road	99.9Km^2(16.5%)	Agricultural	25.7Km^2(15.4%)
Green	86.0Km^2(14.2%)	Residential	5.3Km^2(3.2%)
Commercial	53.9Km^2(8.90%)	-	-
Industrial	7.3Km^2(1.20%)	-	-
Total	605.5Km^2(100%)	Total	167.9Km^2(100%)

Source: Seoul Development Institute (2003). Prioritized Selection and Rearrangement Plan within Seoul Green Belt Areas, p.9.

Confronted with escalating social pressure, the Korean political circle dared to suggest unprecedented measures to reorient the Green Belt regulations. In 1997, the then-presidential candidate, Mr. Dae-Jung Kim, pledged himself to the ‘renovation’ of the Green Belt system as one of his major campaign promises. From the day of his inauguration, Mr. Kim ordered the government to kick off a full-scale reform procedure. In July 1999, putting an end to a nearly 30-year-long dispute over the protection of legally-designated green zones, Kim’s government decided to drastically lift restrictions on the development of the Green Belt Areas (see Table 2).[7] They focused on complete removal of Green Belt systems in the medium-sized cities and partial adjustment in the large cities including Seoul and the Capital Region. The key points of the new official GB documents were given to a clear-cut resolution of procrastinated complaints and various inconveniences, mainly from the aboriginal landowners.

Table 2. Tentative Green Belt Rearrangement Plan in the Capital Region

Categories	GB Designated Area (A)	GB Cancelled Area (B)	Percentage B to A (%)
Capital Region	1,566.80Km^2	123.86Km^2	7.9
Seoul Metropolitan Government	167.92Km^2	3.55Km^2	2.1
Gyeonggi Province	1,302.08Km^2	112.01Km^2	8.6
Incheon Metropolitan Government	96.80Km^2	8.30Km^2	8.6

Source: Lee, J. J., and C. S. Lee (2002). “Housing Complex Construction Problems and Improvement Measures on Ex-Green Belt Areas,” Proceedings of Conference on Rental Housing Construction on Ex-Green Belt Areas and Basic Premises, p.24.

By 2002, for example, local governments within the Capital Region had to quickly draw up master plans centered around canceling 123.86Km^2 of the existing

Green Belt-regulated 1,566.80Km^2. In the same year, the Ministry of Construction and Transportation was also ready to implement an ambitious rental housing construction plan of 40,000 units within ex-Green Belt areas as a strategic means to ameliorate acute housing problems in the Capital Region. Furthermore, the central government initiated a series of streamlined administrative processes to accelerate local governments' Green Belt removal.

All of a sudden, a huge amount of land previously under the Green Belt regulations has been targeted for high-density housing complexes and other urban facilities, while diminishing the green areas under the strictest development control. The abrupt change in Green Belt policy has provoked another round of serious debates between pro and anti. The anti-Green Belt groups have insisted that the Green Belt regulations have rather increased social costs. They have even suggested that the Green Belt has made urban management inflexible to dynamic socio-environmental changes. Even though the legally designated green zones have contributed to checking the formation of urban conurbation, critics argue that these types of artificial strokes have increased social costs, requiring additional public facilities and extending commuting distance, all of which have led to leap-frogging development around the outskirts of Seoul.

In contrast, the pro-Green Belt groups evaluate the existing mechanism as the surest way to keep 'green' in Korean cities. For them, the remaining questions have been usually confined to how to get rid of the ridiculous and unreasonable factors. They also worry that the recent government announcement may aggravate urban problems in Seoul and the Capital Region. And they even demean the authority and confidence of public planning in general. The former refers to the negative impact on quality of life (QOL), including environmental damage from the conversion of Green Belt areas into residential, commercial, and industrial sites.

This explains why diverse environmental activists are unhappy about the government initiative. In the worst situation, they insist, the government move may trigger a real estate speculative boom by boosting land prices within Green Belt areas. Related to the latter, the question of public policy rationality has been raised, as the government tries to reverse the 30-year-old tradition. Altogether, people who think the recent government prescription has gone far beyond correcting the remaining absurdity warn that it would inevitably bring about the expansion of built-up areas within Seoul and the Capital Region, nullifying or weakening the original purposes of explicit urban policies geared toward taming urban problems.

Then, what are the gains and losses of the new government move? The paper tackles these tasks with alternative Urban Dynamic modeling and simulation works. The remaining sections of this paper focus on the formation of causal loops and experiments with stock-flow diagrams ascribed to Green Belt relaxation.

Ⅲ. Causal Loops and Stock-Flow Diagrams of Green Belt UD Models

1. Structure of the Urban System and Major Variables

Primarily, our research interest is given to analyzing how recent Green Belt policy in the Capital Region is interrelated with various urban subsystems of Seoul. We also measure major changes in urban dynamics. For these purposes, we figure out the alternative causal maps dealing with Seoul's urban dynamics and develop a couple of simulation models.

The paper follows traditional approaches revolving around triplicate subsystems of population, housing, business, and transportation, all of which are frequently used by Alfeld and Graham (1976), Ness and Low (2000), Moon (2002), and Choi (2003).

Table 3. Green Belt UD Variables and Data Sources

Urban Subsystems	Key Variables	Data Sources of Key Variables
Green Belt and Environment	Green Belt Areas, Green Belt Cancellation Areas, Green Area, Environment Capacity, Waste Volume, Air Pollution Volume, Air Pollution Level, Environment Invest, Landfill, Landfill Capacity	Kwon, Y. W., and B. S. Byun (2003), Moon, T. H., and M. S. Hong (2001), Ministry of Science and Technology (1991), Lee, C. W. (2000), *2020 Seoul Master Plan* , KRIHS (1998), Lee, J. J., and C. S. Lee (2002), *White Book of Seoul Environment*, *Seoul Environment Statistics*, Min, M. K. (2000), Lee, S. H. (1998), SLSMC (2002), *Statistical Yearbook of Seoul*, Lee, D. G. (1998)
Population	Seoul Population, Household Number, Birth Rate, Death Rate, In-migration Rate, Out-migration Rate,	Choi, S. Y., and K. Y. Kim (2003), Oh, Y. P., and J. H. Kang (2002), Kim, S. Y., and B. S. Lee (2001), Kim, M. H. (1998), *Forecasting of Future Population in Local Government*, *Statistical Yearbook of Seoul*, *Statistical Yearbook of Population Movement*, *Statistical Yearbook of Incheon*, *Statistical Yearbook of Gyeonggi*, *Impact and Counter-Measure against Large-Scale Development Project in the Capital Region*.
Housing	Housing Number, Average Housing Size, Housing Construction Records, Housing Price, Residential Areas, Floor Area Ratio, Building-to-Land Ratio	Byun, C. H., and H. J. Lee (2002), Choi, Y. K. (2002), Choi, M. J. (2001), *Statistical Yearbook of Seoul*, *Statistical Yearbook of Incheon*, *Statistical Yearbook of Gyeonggi*, *Statistical Yearbook of Construction and Transportation*, *Trends in Housing Price*
Local Economy	Business Unit, Employment Number, Start-up Unit, Bankruptcy Rate, GRDP, Budget, Financial Expenditure, IT Impact	Kim, D. K. (2003), Kim, J. S. (2001), Kim, J. S. (2001), Park, J. S. (2001), *Statistical Yearbook of Local Finance*, *Statistical Yearbook of Seoul*, *Economic Impact Assessment of Telecommunication Industry*, *Statistics of Bankrupt and Start-up Companies*, *Start-up Company Trends*
Transportation	Car Number, Road Area, Traffic Volume, Average Traffic Speed, Transportation Investment, Transportation Tax	Kang, K. W., and W. K. Kook (2001), Ahn, H. K. (2001), Seo, J. G. (1998), *Statistical Yearbook of Seoul*, *Traffic Indicators and Analyses of Traffic Characteristics*, *Regular Survey Materials of Vehicle Speed*
The Rest	Variables Related to Information	Kim, H. B., and Y. H. Cho (2002), Maeil Business Economy (2002), Lee, B. S., H. T. Ahn, and J. J. Kim (2001)

Table 3 summarizes the existing Korean documents from which key variables of urban subsystems in Seoul are selected. Among these, the paper pays attention to variables that exert a significant impact on both the concept of sustainable development and quality of life in and around Seoul. In terms of geographical model boundaries, as the Non-Seoul Capital Region (Gyeonggi Province and Incheon Metropolitan Government) puts forth indirect impact on urban subsystems of Seoul, it also presents variables originating from the Gyeonggi and Incheon areas.

To check where there exist circular relationships among variables, we apply a couple of methods. First of all, we observe behaviors of level and rate variables in a practical manner. Secondly, we reexamine theoretical meanings from the existing urban dynamics approaches. Thirdly, we try to refine modeling works through group modeling techniques as well as professional consulting, which would minimize subjective judgments.[8] In sum, intra and inter-system analyses are juxtaposed in the diagrams, ahead of tracking down the loci of main feedback loops.

2. Causal Loop and Stock-Flow Diagrams of Green Belt UD Models

Causal loops function as an anchor for the stock-flow diagrams and a basic tool to interpret simulation results. Figure 1 presents Green Belt loops hinged on the urban dynamics of Seoul. Considering the multifaceted urban structure, theoretically more than 200 loops can be created. Nonetheless, the 19 feedback loops in the paper seem quite sufficient in divulging the dynamic structure and character of the Seoul Green Belt.

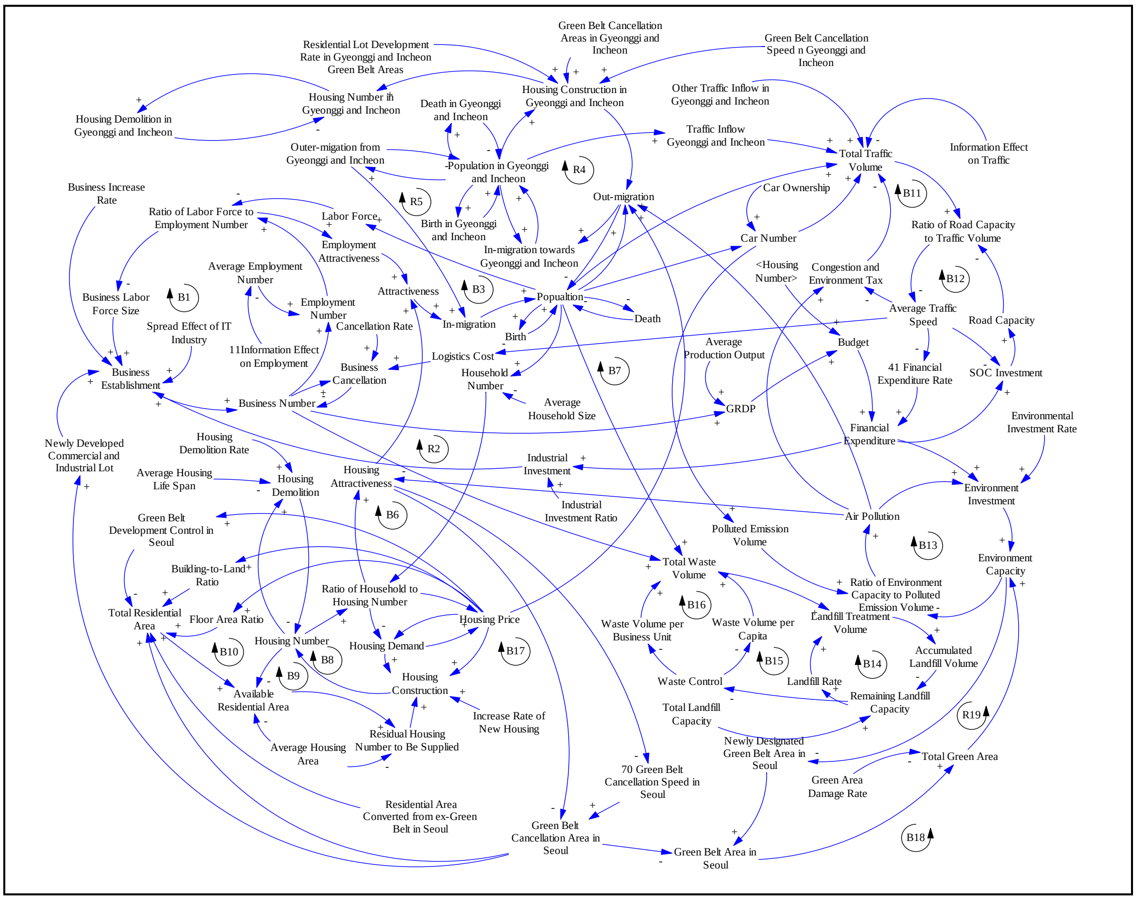

Figure 1: Green Belt Causal Loops

The very first loop B1 presents a negative feedback originating from suppressing business start-ups, as newly added commercial and industrial sites resulting from partial GB cancellation invite new businesses. In this situation, the acquirement of industrial labor forces in Seoul becomes relatively difficult.

R2 implies that there exist positive relationships between business, GRDP, budget and financial expenditure, even though the effect of financial expenditure on business contains a time delay.

B3 as a negative feedback for balancing urban population change lowers the attractiveness of employment. Even though in-migrated people increase the size of the labor force, it also reduces the job availability in Seoul.

R4 exerts a positive impact on Gyeonggi and Incheon's population. The shrink of Green Belt areas in the Capital Region sends two opposite signals: out-migration in Seoul and in-migration in Gyeonggi and Incheon as the government policy change makes residential development on the ex-Green Belt areas possible. The causal relationship between Seoul and the remaining Capital Region can be strengthened, as the average size of newly developed housing complexes in Gyeonggi and Incheon is relatively bigger than that of Seoul.

In contrast, R5 presents the opposite loci of population movement. The expected in-migration from Gyeonggi and Incheon would increase Seoul's population.

B6 displays the fact that housing attractiveness in Seoul would increase, as the land use of the ex-Green Belt areas within Seoul would be designated for residential use, relaxing housing problems. However, this movement would contribute to lowering housing attractiveness, as the ratio of housing number to household would deteriorate, mainly owing to the increased in-migration.

In theoretical perspectives, B7 presents the fact that ever-increasing housing price would dampen in-migration aspiration from the rest of Korea to Seoul: it would rather instigate out-migration from Seoul and a resulting population decrease in Seoul. If this happened, the ratio of housing number to household would increase, lowering housing price.

B8 is more or less straightforward. In this perspective, negative relationships between housing construction, housing number, and household and housing price.

B9 also yields a negative loop, as the increase in housing number would reduce the available residential areas, diminishing the residual housing number to be supplied.

In B10, the pressure of housing price influences a series of factors including Green Belt development control, building-to-land ratio, and floor area ratio, all of which would change the structure of the total residential area, available residential area, and residual housing number to be supplied.[9]

B11 in the upper right corner shows a negative feedback loop in the transportation sector. The increased population and car numbers would expand total traffic volume, which in turn would decrease the ratio of road capacity to traffic volume. As a result, average traffic speed would be reduced. If the Seoul Metropolitan Government introduces congestion and environment tax to discourage car ownership, it will yield a negative impact on the traffic volume.

If traffic congestion becomes a chronic issue, regardless of rush hour, the last resort may be SOC investment to recover road capacity. In this context, B12 represents the negative relationship between road capacity and the ratio of road capacity to traffic volume.

B13 focuses on environmental issues. The increased volume of air pollution would definitely increase the ratio of environment capacity to the polluted emission volume. Under these conditions, the expansion of environment capacity through enlarged environment investment could temporarily halt or slow down the deterioration of air quality.

The negative feedback loops from B14 to B16 deal with waste issues, indispensable components in urban life.

B17 shows a series of impacts originating from residential use of ex-Green Belt areas. This conversion makes it possible to expand housing number and housing attractiveness. Increased housing attractiveness, in turn, would decrease the desire to convert the Green Belt into other purposes.

The relationship between the Green Belt and the environment in a broader context is presented in B18. That is, if the Green Belt areas in Seoul were reduced, it would provide different momentum: decreasing environment capacity vs. increasing level of air pollution. As a result, lowered housing attractiveness becomes inevitable, which would again slow down the Green Belt conversion speed.

The last loop B19 proposes a radical solution, reversing the current fashion. It implies that the Seoul Metropolitan Government should expand Green Belt-regulated areas as a practical means to upgrade the quality of life (QOL). As the Korean government has relaxed Green Belt regulations more than 50 times since its inception, nonetheless, the reorientation of Green Belt policy seems implausible for the time being.

Based on the causal loops, Figure 2 presents stock-flow diagrams for the Seoul Green Belt. The stock-flow diagrams are used to analyze behavioral changes of the urban dynamics, in addition to simulation exercises.

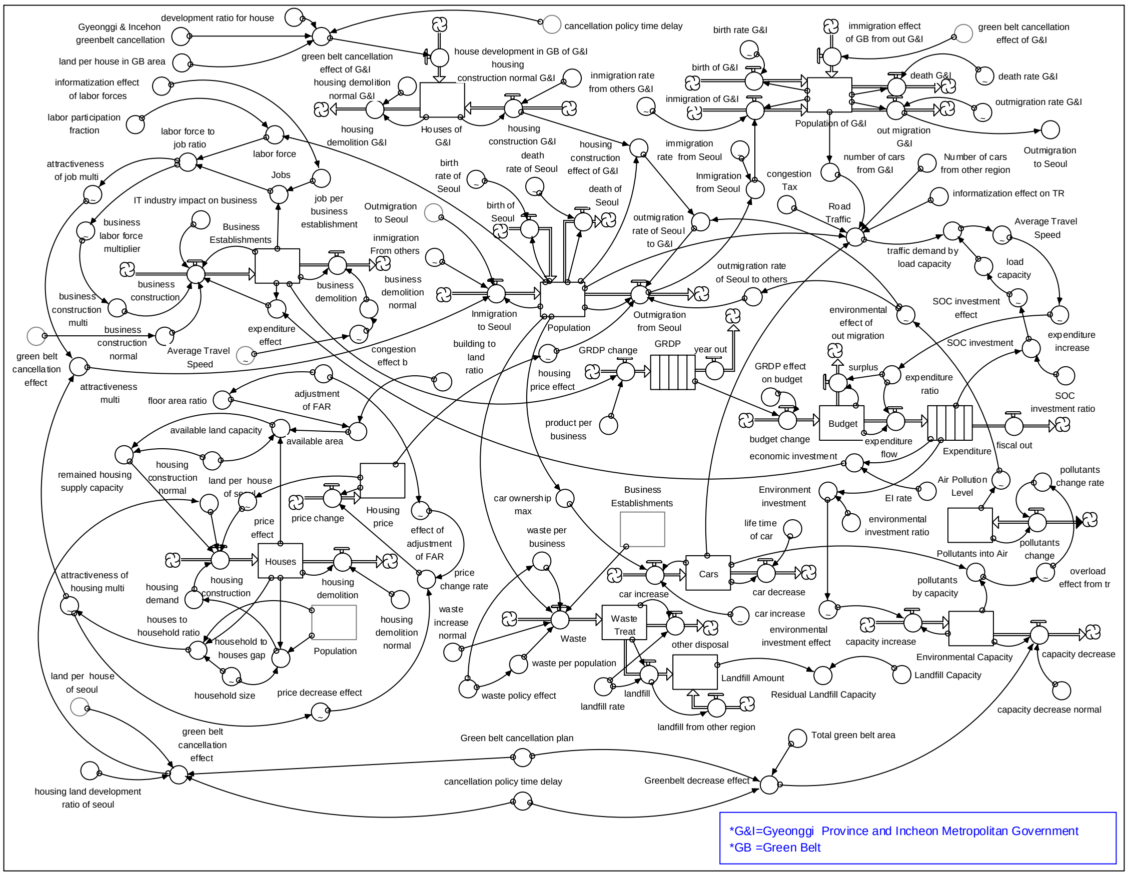

Figure 2. Stock-Flow Diagrams for Seoul Green Belt

Ⅳ. Simulation Results of Green Belt UD Models and Policy Implications

1. Population, Housing, and Employment

This research sets up alternative UD models to analyze long-term behavioral patterns of urban subsystems in Seoul and the Capital Region, now experiencing the effects of an abrupt change in Green Belt policy. Simulation works for the basic model focus on the system dynamics if the planned cancellation of existing Green Belt areas. Policy sensitivity tests are carried out in the second stage.

Following UD traditions, behavior changes and their patterns of population, housing, business units and employment numbers from 2001 to 2030 are summarized in Figure 3. For the next three decades, Seoul's population would continuously decrease, reaching about 8.63 million in 2030. In spite of the partial cancellation of Seoul Green Belt areas under the strictest development control, Seoul is destined to lose its population--increased out-migration into Gyeonggi and Incheon with lower population and housing density, not to mention cheaper housing prices. Both non-Seoul Green Belt cancellation and its development impact offer self-reinforcing power for out-migration, pushing almost 1.5 million Seoulites to relocate to Gyeonggi and Incheon.

Owing to extremely low housing ownership (63.9% in 2000), household numbers in Seoul are expected to expand to 2.88 million units by 2030. The in-migration to Seoul would peak around 2008 when most residential complexes including rental units on the ex-Green Belt areas would be developed.

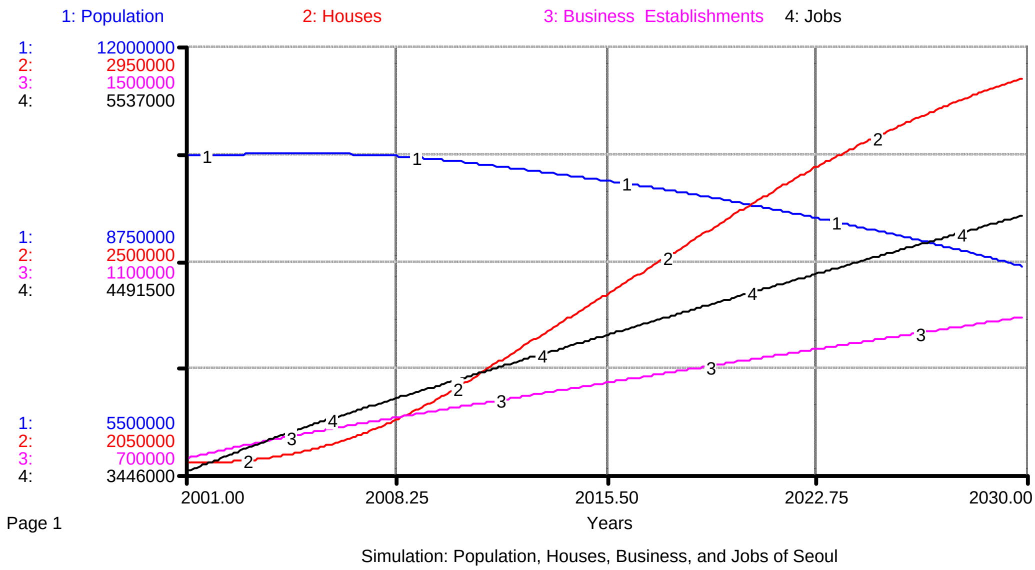

Figure 3. Patterns of Population, Housing, Business Units, and Employment Numbers in Seoul

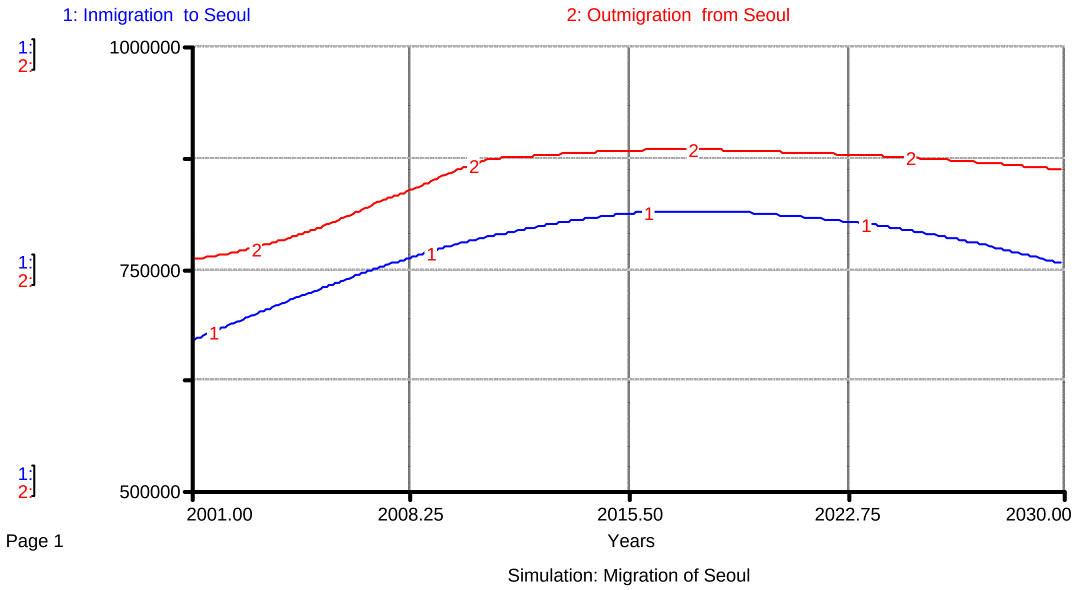

Figure 4. In- and Out-migration Patterns in Seoul

Table 4. Population Movement between Seoul and the Remaining Capital Region (Gyeonggi and Incheon) between 2000 and 2002

Categories		2000	2001	2002
Out-migration	Seoul->Incheon	52,829	52,865	55,500
	Seoul->Gyeonggi	435,573	499,575	516,765
	(Subtotal)	488,402	552,440	572,265
	Seoul->Non-Capital Region	195,515	199,127	179,560
	(Out-migration Total)	683,917	751,567	751,825
In-migration	Incheon->Seoul	45,970	46,213	45,171
	Gyeonggi->Seoul	312,616	319,738	321,390
	(Subtotal)	358,586	365,951	366,561
	Non-Capital Region->Seoul	278,392	271,757	278,843
	(In-migration Total)	636,978	637,708	645,404
Net Migration between Seoul and the Capital Region		-129,816	-186,489	-205,704
Net Migration of Seoul		-46,939	-113,859	-106,421

As migration characteristics between Seoul, Gyeonggi, and Incheon are interrelated, nonetheless, it seems inevitable that Seoul will lose its population under the relaxed Green Belt policies in the long run. As shown in both Table 4 and Figure 4, the volume of out-migration has already surpassed that of in-migration. Furthermore, it is estimated that the population increase rate of Gyeonggi and Incheon will exceed that of Seoul, accelerating population decrease in Seoul. Figure 5 presents the simulated change of population and housing units.

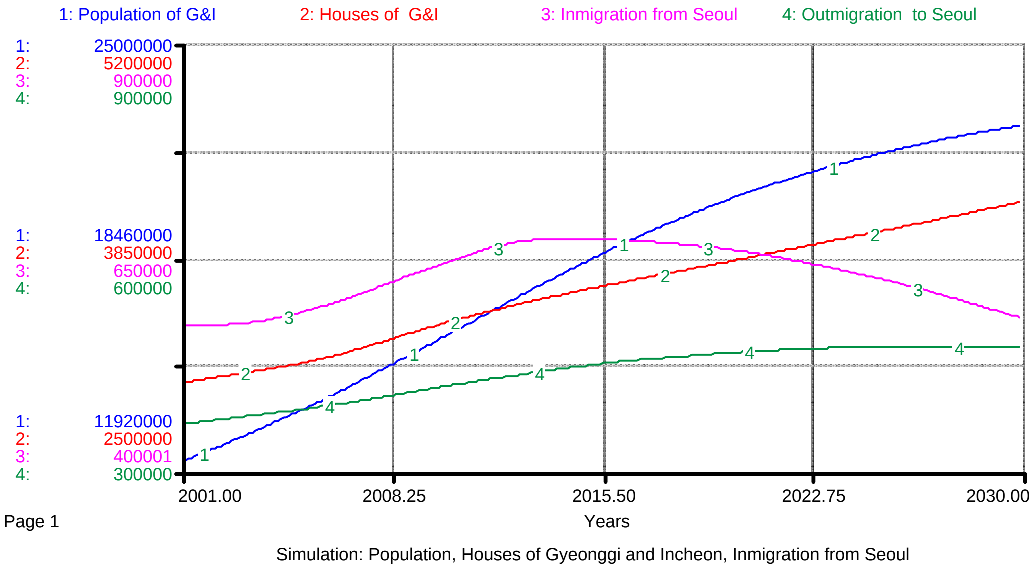

Figure 5. Patterns of Population and Housing Units in Gyeonggi and Incheon

2. Local Economy and Finance

In 2003, business units and employees in Seoul were 72.5 million units and 3.45 million people, respectively. As shown in the previous Figure 3, the basic model assumes that more than a million business unit and 4.76 million employees are possible in 2030. The incrementally increasing pattern reflects the fact that the Korean government has opted for a location strategy which concentrates IT-related industries in Seoul. Furthermore, without damaging the business labor force multiplier, the model supposes, business can find appropriate employees. Under these conditions, the impact of the Seoul Green Belt cancellation is meager, or at worst nominal, in expanding business activities. If it comes true, the anti-Green Belt campaigners may exaggerate the effect of Green Belt cancellation, contrary to their argument that the Green Belt regulations have rather made business activities flexible, losing their competitive edge and raising the question of social costs.

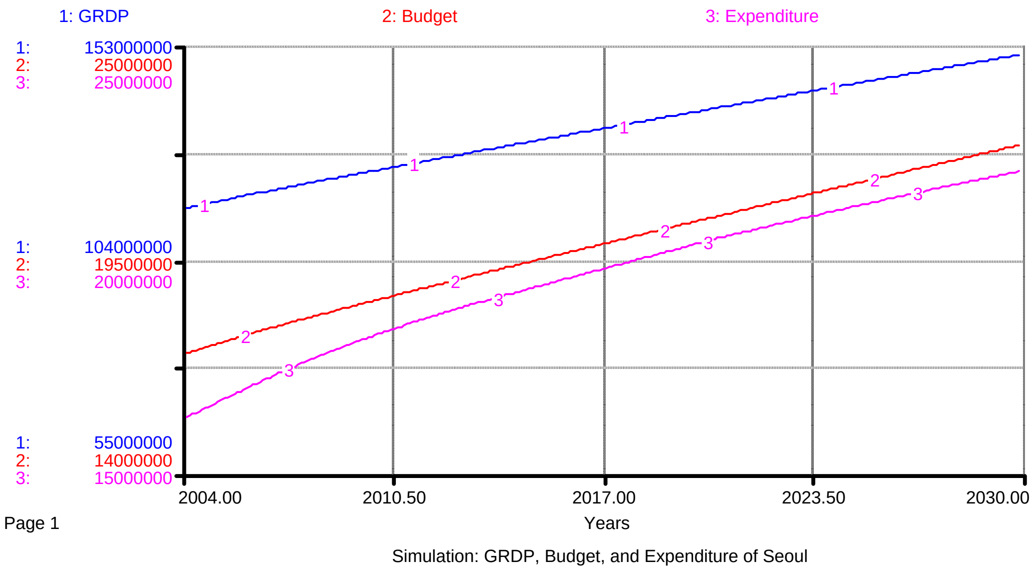

Figure 6. Patterns of GRDP, Local Tax Revenue, and Expenditure in Seoul

Figure 6 presents patterns of GRDP, local tax Revenue, and expenditure in Seoul. The direction of these indicators is the same as that of local economies. This reflects the fact the reinforcing feedbacks between local economies and local finance.[10]

3. Transportation Sector

Figure 7 runs through transportation indicators like car number, traffic volume, and average traffic speed. Seoul's car number would record its highest level in 2013(3.02 million units), but it would reduce to 2.58 million units in 2030. A similar pattern is observed in traffic volume. Behavior patterns of car number and traffic volume can be explained through a causal loop relationship with average traffic speed. That is, the total amount of car and traffic volume will reduce average traffic speed from the current 18Km/h to 15Km/h by 2014. After 2015, average traffic speed would increase as the absolute number of cars would lessens, mainly owing to an uninterrupted drop in the population size of Seoul. Nevertheless, by 2018 its impact would not be so significant as the input of traffic volume out of Seoul would continually expand. It may sound paradoxical, but the traffic congestion per se is the key means to improve the traffic situation, substituting continuous investment in the transportation sector.

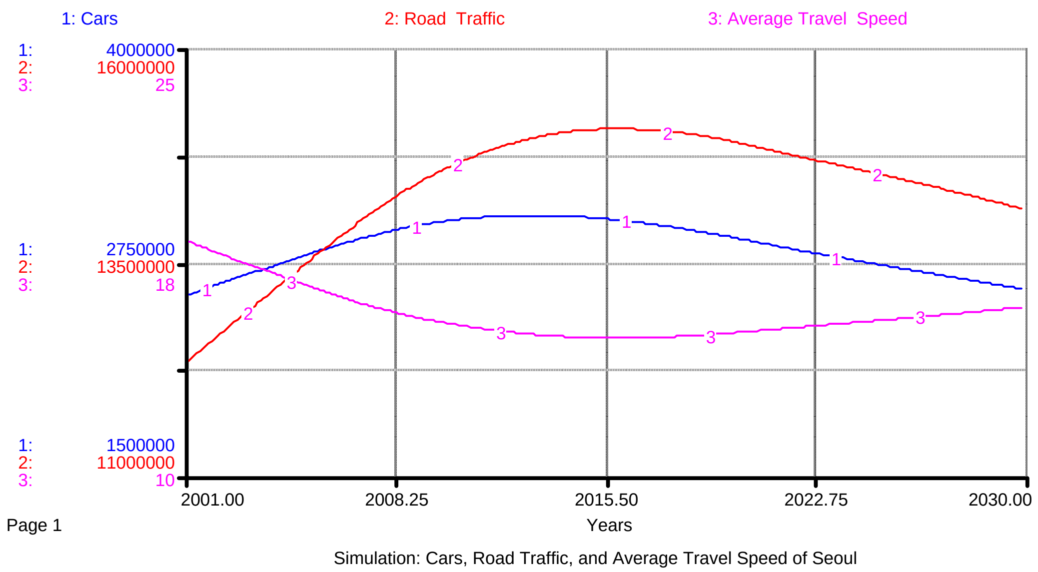

Figure 7. Patterns of Transportation Indicators in Seoul

4. Environment Sector

Patterns of environment indicators are presented in Figure 8. Here, even though environment investment stays at current levels, environment capacity measured in CO^2 absorption level would diminish over time, from the current 1.7 million tons to 1.26 million tons in 2030. In contrast, air pollution levels would deteriorate in the same period: the current 0.13ppm in 2002 will reach 0.19ppm by 2030, simply reflecting the accumulation of polluted materials.[11] The worsening air pollution in Seoul would expedite out-migration to other areas, diminishing the population size of Seoul.

Mashayekhi (1993) presents a system model to analyze the solid waste disposal problem in New York State. His model shows that a rapid response by local authorities to increase the solid waste budget and to lower solid waste generation per capita is necessary to manage the transition from a landfill-dominated mode of disposal to other disposal alternatives and less illegal dumping. In a similar context, Figure 9 represents the reinforcing feedback of waste generation in the Capital Region. The increased waste volume would shorten the life span of the landfill site. Existing documents estimate current landfill capacity at almost 150million tons. If current trends continue, however, the remaining capacity would rapidly decline, reaching zero around 2016, 5 years ahead of the planned closing of the landfill site.

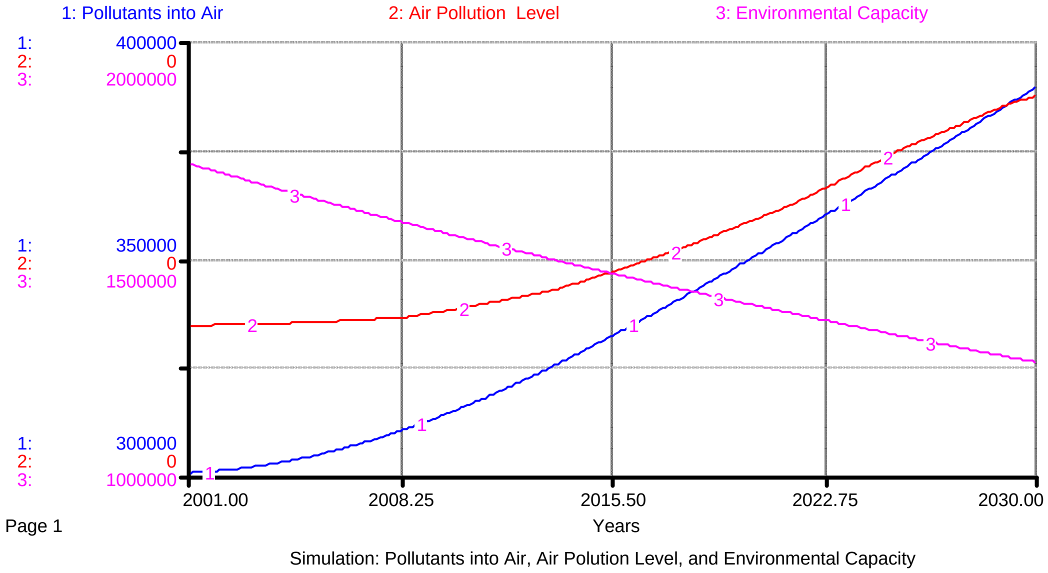

Figure 8. Patterns of Environment Indicators in Seoul

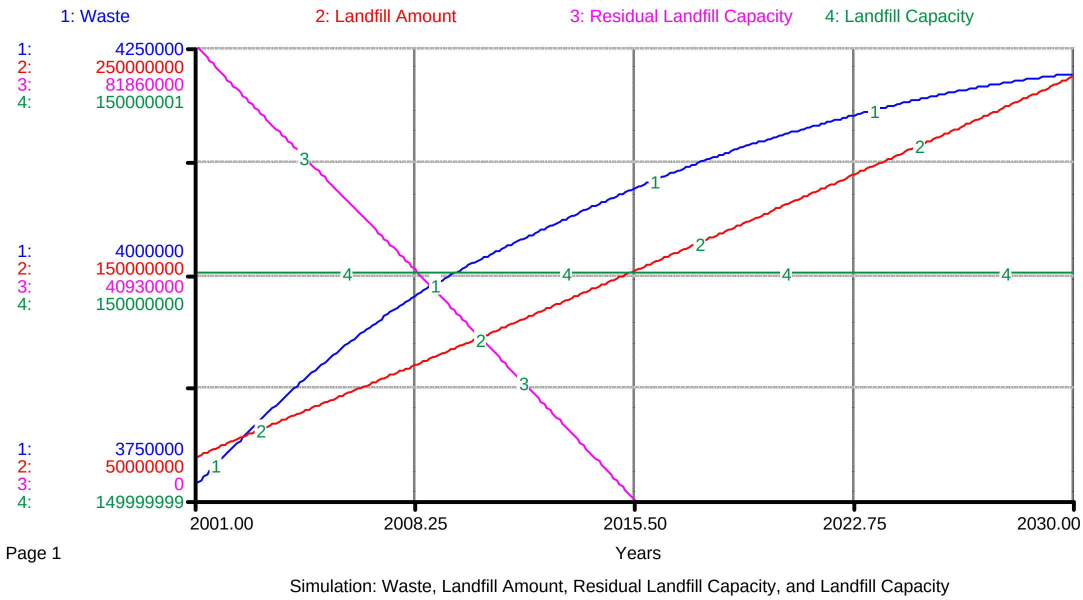

Figure 9. Waste Volume, Landfill Treatment Volume, and Remaining Landfill Capacity in Seoul

5. Policy Sensitivity Test

To test whether the above models respond plausibly when subjected to extreme policy changes, we presuppose an additional cancellation of Green Belt areas. At the moment, the planned Green Belt cancellation areas in the Capital Region are confined to 123.86Km^2 (3.55Km^2 in Seoul and 120.31Km^2 in Gyeonggi and Incheon, respectively). What happens if the Korean government initiates another round of Green Belt readjustment in the Capital Region? For illustrative purposes, we assume the newly Green Belt-cancelled areas = 0.25*the existing stock.

As shown in Figure 10 highlighting only population movement, the estimation yields a similar pattern to Figure 3 and Figure 5. As presented with numbers in Table 5, extra-cancellation of Green Belt areas would produce an 85,000 decrease in Seoul and a100,000 increase in Gyeonggi and Incheon. Simply speaking, these results imply that additional removal of Green Belt areas would rather boost out-migration from Seoul, further disrupting the fragile urban system of the Capital Region.

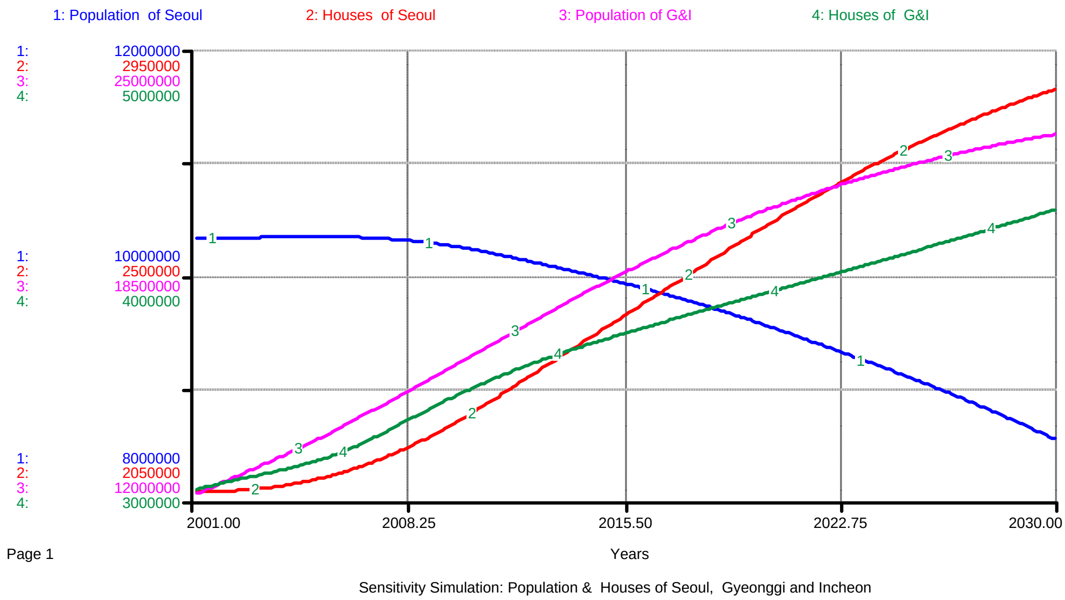

Figure 10. Sensitivity Analysis of Additional Green Belt Cancellation Policy in Seoul and Gyeonggi and Incheon

6. Policy Leverages of Green Belt UD Models

Model simulations facilitate empirical diagnosis of system behaviors at strategic points. Usually, the strategic points focus on a couple of key variables generating a dominant feedback structure and determining the system behaviors. Applicable policy leverages are also derived from these simulations.

Table 6 summarizes both major system behaviors and policy leverages which are shaped by a series of Green Belt UD model simulations. The results imply that policy priorities should be given to housing price control and readjustment of housing construction plans in the Capital Region as a whole, as residential development and housing construction in Gyeonggi and Incheon's ex-Green Belt areas take over those of Seoul, accelerating the out-migration trends in Seoul. In specific, readjustment of floor area ratio, building-to-land ratio, and Green Belt cancellation areas seems inevitable. Other possible policy leverages include reorientation of employment capacity and government expenditure to boost the local economy, traffic demand control, recovery of environment capacity and waste-generation control.

Table 5. Population Change Based on the Green Belt Enlargement Policy in Seoul and Gyeonggi and Incheon

Year	Basic Model (People)		Policy Sensitivity Model (People)	
	Seoul	Gyeonggi/Incheon	Seoul	Gyeonggi/Incheon
2001	10,331,244	12,193,593	10,331,244	12,193,593
2002	10,335,728	12,565,558	10,335,710	12,565,558
2003	10,341,610	12,941,544	10,341,539	12,941,544
2004	10,346,992	13,326,345	10,346,840	13,326,838
2005	10,349,654	13,728,759	10,349,472	13,733,510
2006	10,346,960	14,154,881	10,346,927	14,169,630
2007	10,336,713	14,604,273	10,337,128	14,633,393
2008	10,317,071	15,066,161	10,318,262	15,109,058
2009	10,287,251	15,533,324	10,289,361	15,586,021
2010	10,246,894	16,004,851	10,249,700	16,063,372
2011	10,196,362	16,477,662	10,199,207	16,539,297
2012	10,141,729	16,952,041	10,143,583	17,015,406
2013	10,086,087	17,425,694	10,085,773	17,490,411
2014	10,029,235	17,887,232	10,025,631	17,953,527
2015	9,970,242	18,332,135	9,962,399	18,400,523
2016	9,908,428	18,759,134	9,895,703	18,830,183
2017	9,842,423	19,166,662	9,824,458	19,240,836
2018	9,771,762	19,552,562	9,748,299	19,630,119
2019	9,695,907	19,914,937	9,666,801	19,995,955
2020	9,614,109	20,249,004	9,579,401	20,333,440
2021	9,528,685	20,556,622	9,488,196	20,644,348
2022	9,441,744	20,841,654	9,395,292	20,932,521
2023	9,352,626	21,107,976	9,300,431	21,201,898
2024	9,261,012	21,355,462	9,203,407	21,452,283
2025	9,166,430	21,584,719	9,103,710	21,684,120
2026	9,068,078	21,797,462	9,000,474	21,899,065
2027	8,965,843	21,993,235	8,893,324	22,096,672
2028	8,859,188	22,172,643	8,781,944	22,277,642
2029	8,747,548	22,337,136	8,665,973	22,443,491
2030	8,631,068	22,486,823	8,545,155	22,594,278

Table 6. System Behaviors and Policy Leverage at the Strategic Points

Sector	System Behaviors	Policy Leverage
Population	*Out-migration from Seoul, mainly from the increased housing construction in Gyeonggi and Incheon	*Housing price control in Seoul *Readjustment of housing construction plans in the Capital Region
Housing	*Increase of housing number and residential areas, owing to Green Belt cancellation in the Capital Region	*Readjustment of floor area ratio, building-to-land ratio, and Green Belt cancellation areas
Local Economies	*Increase of business unit	*Reorientation of employment capacity and government expenditure
Transportation	*Increase of traffic demand in the Capital Region	*Traffic demand control
Environment	*Decrease of environment capacity and increase of waste	*Recovery of environment capacity *Waste-generation control

Ⅴ. Conclusions and Discussions

As a sweeping change in Green Belt policy would exert a significant impact on urban dynamics, GB issues have caused serious debate in Korea. This research tries to synthesize the dichotomized opinions between anti- and pro-Green Belt campaigners. Specifically, we examine the behavioral changes of urban dynamics if the Green Belt regulations in Seoul and the Capital Region at large are readjusted. Based on the data available, we focus on long-term trends in various urban subsystems including population, housing, local economies, transportation, environment. Contrary to the large volume of statistical approaches, this research applies UD modeling tools, covering causal loop formation and computer simulations.

The following summarizes the major findings. Firstly, this research reconfirms the fact that the various urban subsystems in Seoul contain a built-in structure of causal loops. Therefore, changes in the subsystem variables make movement of system structure nonlinear and dynamic. Secondly, the feedback structures of Seoul and the Capital Region play an important role in determining the urban dynamics of Seoul. That is, as housing construction in the Capital Region and out-migration in Seoul are interconnected, the former has considerable influence upon the population size of Seoul. Thirdly, Green Belt cancellation in Seoul will not contribute to population increase in the long run. Rather, the new Green Belt policy would make Seoul lose more than 1.5 million people or so over the next three decades, as the remaining Capital Region also adopts similar residential development plans on ex-Green Belt areas. Considering self-controlling housing and population mechanism in the Capital Region, abnormal housing prices in Seoul entail a growth limit. Fourthly, the current government-initiated Green Belt cancellation and adjustment would result in deterioration of the overall quality of life in Seoul. Simply stated, the new Green Belt policy would be confronted with tricky or wicked urban problems; it may lower average traffic speed, not to mention worsening air pollution levels in Seoul. For example, the Seoul Metropolitan Government may put a huge amount of money into environment improvement. At the same time, it may stick to the urban master plan of reducing green areas like the Green Belt. These two different policy orientations, however, may invite series urban problems and dampen efforts for sustainable and sound development.

These results imply that Seoul's current urban system does not represent any type of stable conditions. An abrupt policy change may cause unprecedented out-migration in Seoul and corresponding in-migration in the remaining Capital Region. Judging from these research findings, in order to gain necessary and sufficient conditions to ameliorate urban problems, we pay attention to divulging urban dynamics and emphasizing the feedback structures of urban systems. In other words, stakeholders, including both citizens and policy makers, should decide how to deal with the major trade-off questions on the urban policy agenda.

Notes

[1] Bertuglia et. al. (1987) suggest similar concepts of an urban system, which can be seen as a set of elements (subsystems) interacting with each other through socio-economic and spatial mechanisms. They put forward five main subsystems: housing market, job market, service sector, land market, and transport. The corresponding variables for describing the structure of an urban system are population, housing stock, industry (economic base), services, land use, and traffic flow.

[2] For example, Shimada, et. al. (1986) formulates rather simple models to represent the relationship between the ward area and the four adjoining districts in the Tokyo Metropolitan Region. Santos (1996) demonstrates how the original city plans in Brasilia have been replaced by the internal dynamics of growth. Sancar and Onaran (1997) use SD dynamics to formulate research in land use planning by modeling the dynamics of 'informalization' in land use control. Saeed (1998) focuses on both urban dynamic systems and carrying capacity, stressing the concept of sustainable development. Wolfeden (1999) suggests an urban ecological approach based on interdisciplinary methodology to explain the subtle relationship between urban dynamics and resource management. Experimenting with the computer program STELLA for four Asian cities, Ness and Low (2000) propose a closed-system model for examining urban population-environment dynamics, inevitably ignoring both the external sources of urban problems and their impact on exogenous variables. Kim, Moon, and Kim (1999), Moon (2000, 2002), Hong, et. al. (2000), Choi (2003), and Lee and Lee (2004) have paid attention to the UD methodologies in interpreting urban phenomena in Korea.

[3] As Harvey (1973) describes, it should nonetheless be remembered that social justice and efficiency are very much same thing in the long run.

[4] To analyze the interdependencies among public policies and improve the policymaking process at the national level, Lim (1988) presents a theory and a taxonomy explaining relationships among policies in three spheres—sector, distribution, and space. Even though Lim summarizes his ideas in a table, they can be paraphrased as a causal loop diagram, which could be later transformed into a stock and flow diagram in order to estimate dynamic changes of the major variables over time.

[5] While the land ratio of Seoul to the nation is only 0.6%, its population share is 21.4% as of 2000, a drastic increase from 9.8% in 1960. In addition, the land proportion of the Capital Region including Seoul is 11.8%, but its population share grew from 20.8% in 1960 to 46.3% in 2000. It seems that Seoul and the Capital Region has rather strengthened key roles

in most socio-economic and cultural activities, which doesn't ameliorate typical territorial problems.

[6] Whilst business circle's outcry for the deteriorating business environment continues, a few companies are also blamed for being eager to indiscriminately purchase land throughout the Korean peninsula, rather than trying to acquire profit from normal business activities. In general, issues concerned with real estate speculation in Korea have been so volatile as to easily expand the social gap between the have and the have-not.

[7] In 1998, the Constitutional Court of Korea ruled that the existing Green Belt systems were not partially in accord with the Constitution, overly infringing the property rights of citizens. To follow the Court ruling, Kim's government had to take immediate actions.

[8] Seven Korean professionals joined the various stages of group modeling, in addition to the authors. Group modeling based on consensus building is regarded as a short cut to increase the model's objectivity (Vennix 1999).

[9] Both building-to-land ratio and floor areas ratio follow the Seoul Metropolitan Government's standards (Byun and Lee 2002).

[10] Park (1997) confirms a causal relationship between GRDP and local finance. In his research, a 1% growth of GRDP makes a tax revenue increase of 0.97%.

[11] *White Book of Seoul Environment* (2001) reports that 84 percent of air pollution materials in Seoul comes from automobiles.

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Appendix: Simulation Functions for Green Belt UD Models

Budget(t) = Budget(t - dt) + (budget_change - expenditure__flow - surplus) * dt
INIT Budget = 15624796
INFLOWS:
budget_change = GRDP*GRDP_effect_on_budget
OUTFLOWS:
expenditure__flow = Budget*expenditure__ratio
surplus = Budget*(1-expenditure__ratio)
business__establishments(t) = business__establishments(t - dt) + (business__construction - business__demolition) * dt
INIT business__establishments = 725569
INFLOWS:

```
business__construction =
(business__establishments)*((business__construction__multi*business__construction__normal)+expendi
ture_effect+IT_industry_impact_on_business)
OUTFLOWS:
business__demolition = business__establishments*business__demolition__normal
Cars(t) = Cars(t - dt) + (car_increase - car_decrease) * dt
INIT Cars = 2550000
INFLOWS:
car_increase = (car_ownership__max-Cars)*car_increase__rate
OUTFLOWS:
car_decrease = Cars/life_time__of_car
environmental_capacity(t) = environmental_capacity(t - dt) + (capacity_increase - capacity_decrease) * dt
INIT environmental_capacity = 1714960
INFLOWS:
capacity_increase = environmental_capacity*environmental__investment_effect
OUTFLOWS:
capacity_decrease =
environmental_capacity*(capacity_decrease_normal+DELAY(Greenbelt_decrease_effect, 10))
Expenditure(t) = Expenditure(t - dt) + (expenditure__flow - fiscal_out) * dt
INIT Expenditure = 13423609
    TRANSIT TIME = 1
    INFLOW LIMIT = INF
    CAPACITY = INF
INFLOWS:
expenditure__flow = Budget*expenditure__ratio
OUTFLOWS:
fiscal_out = CONVEYOR OUTFLOW
GRDP(t) = GRDP(t - dt) + (GRDP_change - year_out) * dt
INIT GRDP = 114361985
    TRANSIT TIME = 1
    INFLOW LIMIT = INF
    CAPACITY = INF
INFLOWS:
GRDP_change = (business__establishments*product_per__business)
OUTFLOWS:
year_out = CONVEYOR OUTFLOW
Houses(t) = Houses(t - dt) + (housing__construction - housing__demolition) * dt
INIT Houses = 2068053
INFLOWS:
housing__construction = IF(housing__demand>=remained_housing__supply_capacity) THEN(0)
ELSE(housing__demand*(housing__construction__normal+price__effect))
OUTFLOWS:
housing__demolition = Houses*housing__demolition__normal
Houses_of__K_&_I(t) = Houses_of__K_&_I(t - dt) + (housing__construction_KI + GB_hd_of_K&I -
housing__demolition_KI) * dt
INIT Houses_of__K_&_I = 3051056
INFLOWS:
housing__construction_KI = DELAY(Houses_of__K_&_I*housing__construction_normal_KI, 2)
GB_hd_of_K&I = SMTH3(IF(TIME>=2003 AND TIME<=2006)
THEN(green_belt_cancellation_effect_of_K&I) ELSE(0),5)
OUTFLOWS:
housing__demolition_KI = Houses_of__K_&_I*housing__demolition_norma_KI
Housing__price(t) = Housing__price(t - dt) + (price_change_) * dt
INIT Housing__price =   97.7
INFLOWS:
price_change_ = Housing__price*price_change_rate
landfil_amount(t) = landfil_amount(t - dt) + (landfill + landfill_from_other_region) * dt
INIT landfil_amount = 68136687
```

INFLOWS:
landfill = Waste__Treat*landfill_rate
landfill_from_other_region = landfill*0.7
Pollutants_into_air(t) = Pollutants_into_air(t - dt) + (pollutants__change) * dt
INIT Pollutants_into_air = 300000
INFLOWS:
pollutants__change = Pollutants_into_air*pollutants_change_rate
population(t) = population(t - dt) + (inmigration_S + birth_S - outmigration_S - death_S) * dt
INIT population = 10331244
INFLOWS:
inmigration_S =
(population*(inmigration_From_others+(attractiveness_multi*0.005)))+(outmigration__to_seoul)
birth_S = population*birth__rate_S
OUTFLOWS:
outmigration_S =
population*(outmigration__rate_S_to_KI+housing__price_effect+outmigration_rate__S_to_others+0.017
)
death_S = population*death__rate_S
Population_of_K_&_I(t) = Population_of_K_&_I(t - dt) + (birth_KI + inmigration_KI +
immigration_effect_of_GB_from_out_capital - death_KI - out_migration__KI) * dt
INIT Population_of_K_&_I = 12193593
INFLOWS:
birth_KI = Population_of_K_&_I*birth_rate_KI
inmigration_KI = (Population_of_K_&_I*inmigration_rate__from_others_KI)+(inmigration_from_seoul)
immigration_effect_of_GB_from_out_capital = SMTH3(IF(TIME>=2003 AND TIME<=2006)
THEN(green_belt_cancellation_effect_of_K&I*0.25*3) ELSE(0),3)
OUTFLOWS:
death_KI = Population_of_K_&_I*death_rate_KI
out_migration__KI = Population_of_K_&_I*outmigration_rate_KI
Waste__Treat(t) = Waste__Treat(t - dt) + (waste - landfill - other_disposal) * dt
INIT Waste__Treat = 4368352
INFLOWS:
waste =
(((population*waste_per_population)+(business__establishments*waste_per__business))*(1+waste__incr
ease__normal))
OUTFLOWS:
landfill = Waste__Treat*landfill_rate
other_disposal = Waste__Treat-(Waste__Treat*landfill_rate)
adjustment__of_FAR = 0
attractiveness_multi = attractiveness__of_job_multi*attractiveness_of__housing_multi
available_area = ((301040000*floor_area_ratio*building_to__land__ratio))
available_land_capacity = (available_area)-(Houses*land_per__house_of_seoul)
building_to__land__ratio = 0.6
business__construction__multi = business__labor_force__multiplier
business__construction__normal = 0.02+(100/green_belt__cancellation__effect_)
business__demolition__normal = 0.005+congestion__effect_b
cancellation_policy_time_delay = 1
capacity_decrease_normal = 0.001
car_ownership__max = population* 0.8
congestion__Tax = 0
delelopment_ratio_for_house = 0.45
economic_investment_ = Expenditure*EI_rate
EI_rate = 0.09
environmental__investment_ratio = 0.12
Environment__investment = Expenditure*environmental__investment_ratio
expenditure_effect = ((economic_investment_/1000)*5)/business__establishments
expenditure__ratio = 0.9+expenditure__increase
floor_area_ratio = 3-adjustment__of_FAR

GRDP_effect_on_budget = 0.15
Greenbelt_decrease_effect =
DELAY(((Green_belt_cancellation_plan/Total_green_belt_area)),cancellation_policy_time_delay)*0.5
green_belt_cancellation_effect_of_K&I =
DELAY(((Kyounggi_&_Inchon_greenbelt_cancellation*delelopment_ratio_for_house)/land_per_house_in_GB_area)/4, cancellation_policy_time_delay)
Green_belt_cancellation_plan = 3550000
green_belt__cancellation__effect_ =
DELAY((housing_land_development_ratio_of_seoul*Green_belt_cancellation_plan*land_per__house_of_seoul), cancellation_policy_time_delay)
household_to__houses_gap = (population/household_size)-(Houses)
houses_to__household_ratio = Houses/(population/household_size)
housing_land_development_ratio_of_seoul = 0.0001
housing__construction_effect_of_K&I = (housing__construction_KI/population)*2.5
housing__construction_normal_KI = 0.04
housing__construction__normal = DELAY(0.03*(100/green_belt__cancellation__effect_), 10)
housing__demand = household_to__houses_gap
housing__demolition_norma_KI = 0.03
housing__demolition__normal = 0.0001
informatization_effect_of_labor_forces = 0.05
informatization_effect_on_TR = 0.05
inmigration_from_seoul = SMTHN(outmigration_S*immigration__rate__from_S, 2,6)
IT_industry_impact_on_business = 0.005
jobs = business__establishments*job_per__business__establishment
job_per__business__establishment = 5-(5*informatization_effect_of_labor_forces)
Kyounggi_&_Inchon_greenbelt_cancellation = 120010000
labor_force = population*labor_participation__fraction
labor_force_to__job_ratio = labor_force/jobs
labor_participation__fraction = 0.35
landfill_capacity = 150000000
landfill_rate = 0.84
land_per_house_in_GB_area = 225
land_per__house_of_seoul = 85
life_time__of_car = 12
load__capacity = 7888764*(1+SOC_investment__effect)
number_of_cars__from_K&I = Population_of_K_&_I*0.17
Number_of_cars__from_other_region = 700000
outmigration_rate__S_to_others = (environmental___effect_of__out_migration)+(0.002)
outmigration__rate_S_to_KI = DELAY((housing__construction_effect_of_K&I+0.02-environmental___effect_of__out_migration),2)
outmigration__to_seoul = out_migration__KI*0.6
pollutants_change_rate = -0.02+overload__effect_from_tr
pollutants__by_capacity = Cars/environmental_capacity
price_change_rate = (0.1-price_decrease_effect)+(effect_of__adjustment__of_FAR)
product_per__business = 153
remained_housing__supply_capacity = available_land_capacity*land_per__house_of_seoul
residual_landfill_capacity = landfill_capacity-landfil_amount
road__traffic =
(((population*(Cars/population))*4)+(number_of_cars__from_K&I+Number_of_cars__from_other_region))*(1-congestion__Tax-informatization_effect_on_TR)
SOC_investment = Expenditure*SOC__investment_ratio
SOC__investment_ratio = 0.15
Total_green_belt_area = 166800000
traffic_demand_by__load_capacity = road__traffic/load__capacity
waste_per_population = 0.164-(0.164*waste_policy_effect)
waste_per__business = 2.73-(2.73*waste_policy_effect)
waste_policy_effect = 0
waste__increase__normal = 0.025

air_pollution__level = GRAPH(Pollutants_into_air)
(250000, 0.128), (265000, 0.129), (280000, 0.13), (295000, 0.133), (310000, 0.136), (325000, 0.142), (340000, 0.152), (355000, 0.162), (370000, 0.175), (385000, 0.185), (400000, 0.192)
attractiveness_of__housing_multi = GRAPH(houses_to__household_ratio)
(0.5, 0.502), (0.55, 0.522), (0.6, 0.547), (0.65, 0.578), (0.7, 0.615), (0.75, 0.655), (0.8, 0.705), (0.85, 0.765), (0.9, 0.828), (0.95, 0.907), (1.00, 1.00)
attractiveness__of_job_multi = GRAPH(labor_force_to__job_ratio)
(0.00, 2.00), (0.2, 1.95), (0.4, 1.80), (0.6, 1.60), (0.8, 1.35), (1.00, 1.00), (1.20, 0.5), (1.40, 0.3), (1.60, 0.2), (1.80, 0.15), (2.00, 0.1)
average_travel__speed = GRAPH(traffic_demand_by__load_capacity)
(1.00, 24.8), (1.15, 23.0), (1.30, 21.2), (1.45, 19.3), (1.60, 17.6), (1.75, 16.0), (1.90, 14.6), (2.05, 13.8), (2.20, 13.4), (2.35, 13.2), (2.50, 13.0)
birth_rate_KI = GRAPH(TIME)
(2001, 0.0122), (2003, 0.0113), (2005, 0.0107), (2007, 0.0101), (2009, 0.00985), (2011, 0.00955), (2012, 0.00935), (2014, 0.00915), (2016, 0.0091), (2018, 0.00895), (2020, 0.0088)
birth__rate_S = GRAPH(TIME)
(2001, 0.013), (2003, 0.012), (2005, 0.0112), (2007, 0.0106), (2009, 0.00971), (2011, 0.0092), (2012, 0.00869), (2014, 0.0084), (2016, 0.0081), (2018, 0.00775), (2020, 0.00753)
business__labor_force__multiplier = GRAPH(labor_force_to__job_ratio)
(0.00, 0.2), (0.2, 0.34), (0.4, 0.44), (0.6, 0.54), (0.8, 0.63), (1.00, 0.72), (1.20, 0.78), (1.40, 0.85), (1.60, 0.91), (1.80, 0.95), (2.00, 1.00)
car_increase__rate = GRAPH(TIME)
(2001, 0.048), (2003, 0.0495), (2005, 0.052), (2007, 0.053), (2009, 0.053), (2011, 0.0515), (2012, 0.0505), (2014, 0.0485), (2016, 0.0465), (2018, 0.045), (2020, 0.043)
congestion__effect_b = GRAPH(average_travel__speed)
(15.0, 0.0151), (15.5, 0.0149), (16.0, 0.0145), (16.5, 0.0138), (17.0, 0.0126), (17.5, 0.0111), (18.0, 0.0094), (18.5, 0.0077), (19.0, 0.0056), (19.5, 0.0032), (20.0, 0.00)
death_rate_KI = GRAPH(TIME)
(2001, 0.0042), (2003, 0.00455), (2005, 0.00495), (2007, 0.00525), (2009, 0.0056), (2011, 0.00595), (2012, 0.0063), (2014, 0.0066), (2016, 0.007), (2018, 0.0075), (2020, 0.008)
death__rate_S = GRAPH(TIME)
(2001, 0.0039), (2003, 0.00415), (2005, 0.0044), (2007, 0.0048), (2009, 0.00535), (2012, 0.006), (2014, 0.0066), (2016, 0.00735), (2018, 0.0081), (2020, 0.009)
effect_of__adjustment__of_FAR = GRAPH(adjustment__of_FAR)
(10.0, 0.000125), (20.0, 0.00775), (30.0, 0.0121), (40.0, 0.0155), (50.0, 0.0176), (60.0, 0.0198), (70.0, 0.0213), (80.0, 0.0224), (90.0, 0.0227), (100, 0.0231)
environmental__investment_effect = GRAPH(Environment__investment)
(1.5e+006, 0.00), (1.7e+006, 0.0001), (1.8e+006, 0.000225), (2e+006, 0.0004), (2.1e+006, 0.0006), (2.3e+006, 0.000825), (2.4e+006, 0.00105), (2.6e+006, 0.0013), (2.7e+006, 0.00155), (2.9e+006, 0.00175), (3e+006, 0.00193)
environmental___effect_of__out_migration = GRAPH(air_pollution__level)
(0.1, 0.0002), (0.115, 0.00035), (0.13, 0.00065), (0.145, 0.0009), (0.16, 0.00125), (0.175, 0.0017), (0.19, 0.00215), (0.205, 0.0027), (0.22, 0.00325), (0.235, 0.004), (0.25, 0.0049)
expenditure__increase = GRAPH(average_travel__speed)
(15.0, 0.0985), (15.5, 0.092), (16.0, 0.083), (16.5, 0.0735), (17.0, 0.064), (17.5, 0.056), (18.0, 0.0465), (18.5, 0.0355), (19.0, 0.0245), (19.5, 0.0145), (20.0, 0.0025)
household_size = GRAPH(TIME)
(2001, 3.15), (2011, 2.72), (2020, 2.34)
housing__price_effect = GRAPH(Housing__price)
(100, 0.005), (110, 0.0059), (120, 0.007), (130, 0.0082), (140, 0.0093), (150, 0.0105), (160, 0.0114), (170, 0.0124), (180, 0.0134), (190, 0.0142), (200, 0.0148)
immigration__rate__from_S = GRAPH(TIME)
(2001, 0.75), (2004, 0.76), (2007, 0.769), (2010, 0.772), (2013, 0.767), (2016, 0.757), (2018, 0.745), (2021, 0.727), (2024, 0.704), (2027, 0.677), (2030, 0.65)
inmigration_From_others = GRAPH(TIME)
(2001, 0.0269), (2004, 0.0292), (2007, 0.031), (2010, 0.032), (2013, 0.0326), (2016, 0.0328), (2018, 0.0325), (2021, 0.0316), (2024, 0.0305), (2027, 0.0292), (2030, 0.0272)
inmigration_rate__from_others_KI = GRAPH(TIME)

(2001, 0.0254), (2004, 0.0271), (2007, 0.0283), (2010, 0.0286), (2013, 0.0276), (2016, 0.025), (2018, 0.0224), (2021, 0.0194), (2024, 0.0174), (2027, 0.0158), (2030, 0.0148)
outmigration_rate_KI = GRAPH(TIME)
(2001, 0.0498), (2004, 0.0475), (2007, 0.0454), (2010, 0.0436), (2013, 0.0419), (2016, 0.0404), (2018, 0.0389), (2021, 0.0378), (2024, 0.0368), (2027, 0.0358), (2030, 0.035)
overload__effect_from_tr = GRAPH(pollutants__by_capacity)
(0.00, 0.0006), (0.3, 0.002), (0.6, 0.0046), (0.9, 0.0088), (1.20, 0.014), (1.50, 0.0214), (1.80, 0.0266), (2.10, 0.0316), (2.40, 0.0354), (2.70, 0.038), (3.00, 0.04)
price_decrease_effect = GRAPH(attractiveness_of__housing_multi)
(0.5, 0.00), (0.55, 0.028), (0.6, 0.061), (0.65, 0.086), (0.7, 0.107), (0.75, 0.128), (0.8, 0.149), (0.85, 0.167), (0.9, 0.184), (0.95, 0.196), (1.00, 0.2)
price__effect = GRAPH(Housing__price)
(100, 0.00025), (110, 0.004), (120, 0.00738), (130, 0.0103), (140, 0.0131), (150, 0.0156), (160, 0.018), (170, 0.02), (180, 0.0216), (190, 0.0236), (200, 0.025)
SOC_investment__effect = GRAPH(SOC_investment)
(2e+006, 0.01), (2.2e+006, 0.0102), (2.4e+006, 0.0107), (2.6e+006, 0.0112), (2.8e+006, 0.0117), (3e+006, 0.0122), (3.2e+006, 0.0129), (3.4e+006, 0.0135), (3.6e+006, 0.0141), (3.8e+006, 0.0147), (4e+006, 0.0153)