Urban Land-Use Model to Assess the Effects of Building Cost Support Policy

Shamim Mahabubul HAQUE and Makoto OKUMURA

ABSTRACT

To achieve a desired spatial pattern for any particular city, traditionally land-use controls in terms of zoning regulation are applied. Such zoning regulations are generally very static and are effective when the pace of construction activities in a city is very high. Naturally if construction activities in a city are not very high, consequently very little or nothing to control, such zoning regulations might not have effective role in delivering desired spatial pattern of that city. In this study, a land-use model has been proposed, emphasizing on economic measures of development control/assistance, adding to the traditional static zoning measures. Objective of this research is to build a statistical model to assess the effect of cost assistance policies on the construction activities, expressed in terms of land-use changes, for the study area. A random bid-rent model to describe competitions between four land-use types viz., commercial, industrial, residential and vacant has been developed using physical characteristics, land price information and dummy regulation variables. To assess the effectiveness of such economic measures of development control/assistance, development cost variables (preparation cost for future use and cost/gain from former use) have been explicitly included in formulation of the proposed model. All estimated parameters of the model have been found to be statistically significant and having expected signs. Using estimated parameter values, land-use simulation has been done for the study area and predicted land-use has been found to be reasonably consistent to the observed land-use. Effects of different cost assistance regimes have been illustrated in the present research in terms land-use change of the study area; different cost assistance regimes generate different spatial pattern for the city in terms of different land-use configurations, suggesting the applicability of such type of mechanism instead of strict zoning regulations only.

Keywords: Land-use, Urban Model, Development Cost, Cost Support, Development Control

1. INTRODUCTION

Nowadays, changes in economic and business environment of present day cities and changes in attitudes and lifestyles of city dwellers are altering the needs for various social, economic and physical infrastructures more rapidly than ever before, in terms of their quality, quantity and also geographic distribution. As a consequence of such changes in needs, urban land-use distribution is also changing. For example, traditionally flourished central commercial districts are loosing their competing power to new commercial cores developed at the outskirts of the cities, due to their failure to cope with the new standards of services expected by the new generation urbanites. In order to keep the competing power for traditional commercial core areas, land-use renovation and renewal must be strengthened to keep up with the pace of the changing needs. To achieve desired spatial pattern for cities, traditionally land-use controls are applied in terms of zoning regulation. Such zoning regulations are generally very static, as they are not modified in short term, and authoritarian in nature. Zoning regulations are effective when the pace of construction activities in a city is very high. But, if construction activities in a city are not so high, such zoning regulations, if not modified, might not have effective role in delivering desired urban landscape as many of the urban infrastructures will not be built at right place in right time. However, the need for zoning can not be totally suspected in rapidly changing cities, because it might result a chaotic city structure driven by short term financial interest ignoring long term environmental damages. To facilitate orderly and timely activities for renovation of urban-core, for more effective use of historically accumulated urban infrastructures within the city core, where pace of construction is not so rapid, dynamic assistance/control of development, instead of strict zoning approach only, might be acceptable. Economic measures such as construction cost support might be a very effective policy option for dynamic assistance and control of development in slow growing cities. Such dynamic development control or assistance should be able to stimulate or retard the pace of construction activities in different places of a city depending upon the requirements of a particular place evaluated in terms citizen's expectation under no centralized decision making mechanism. Considering the financial feasibility, such dynamic control or assistant measures could be applied at relatively detailed area level i.e, land lot level.

For predicting urban land-use, traditionally aggregated macro models based on relatively larger zones are used. Such zone-based models have led to serious methodological difficulties such as the 'modifiable area unit problem' and problem of spatial interpolation between incompatible zones (Wegener, 1998). Besides, it is not also possible to assess the effect of any policy interventions designed and targeted in more finer level such as land lot level, even though lot level changes have important implications in deciding spatial pattern of a city. With the advent of GIS and remote sensing technology and with the availability of detailed geographical data in digital format, a more disaggregated model building is now possible, which could free land-use modeling from zone based modeling approaches. An earlier attempts by the authors, (Okumura and Haque, 2002) where detailed land price information were used to build land-use prediction model based on bid-rent functions in real land price term, showed reasonable level of accuracy and opened up the possibility for building land-use models for assessing economic policy measures at land lot level.

Objective of the present research is to develop a statistical model, incorporating detailed land lot level geographic data and price information, which is capable of assessing the effects of cost support policies on land-use changes in the study area. For predicting urban land-uses under economic policy interventions, two cost variables viz., cost of preparation for future use and cost or gain from former use have been explicitly considered in the model formulation.

2. RELATED RESEARCH

Macro urban land-use models in early days relied on regression of observed relationship between geographical characteristics of each zone and land-use. Consequently, such models could not be used to assess policy measures which have not yet been introduced. Lowry's Model of Metropolis (1964) distributed exogenously decided control total to various urban zones according to the relative weights of each of the zones, calculated by spatial interactions among the zones. Through gravity or entropy theory, spatial interactions can be endogenously explained under the influence of geographic characteristics or policy interventions, and therefore, the Lowry Model is considered as the pioneer of operational models. Many operational models have been developed as Lowry derivatives since early 1970's. Of them the Disaggregated Residential Allocation Model (DRAM) and the Employment Allocation Model (EMPAL) are claimed to be "most widely applied models" (Putman 1995). Instead of gravity or entropy concepts, discrete choice model, especially multi-nominal logit model gained popularity in newer generations of the Lowry derivative land-use models. There are some difficulties in applying discrete choice model to land choice behavior, because we does not consider that a locator can compare huge number of possible locations once at a time easily as such model assumes. Subsequently, random bid-rent model has been developed to capture the competition between different locators. Such model suggests that for a certain land lot, several possible locators may give different bid rent according to the expected utility or expected profit. An existing land owner, seeking for maximum profit, selects the locator with the highest bid-rent (Miyamoto et al 1989).

Most of the operational models consider inter-zonal interactions to explain potentials or bid-rents for each of the zones, as a result, such models are built considering traffic analysis zones as smallest spatial unit of analysis. Even the California Urban Futures (CUF) Model, which uses the analytical power of GIS to manipulate the detailed geographical information (Landis, 1995), does not use lot level data. More recently, UrbanSim has been developed using lot-level GIS data (Waddell, 1998), but the location units are still traffic demand forecasting zones. Such confinement of land-use modeling in zone-based system is called as 'tyranny of zones' (Spiekerman and Wegener, 2000) and needs to be alleviated to assess the effect of policy interventions, especially economic policy intervention on city's spatial pattern.

With the increased availability of remotely sensed data and GIS technology, land-use transition at finer spatial resolution level started attracting attentions of researchers, partly due to the progress of Cellular Automata approach in urban modeling. But if we want to introduce effects of economic policy intervention such as tax or cost support, mechanical CA transition rules turn out to be insufficient. Miyamoto et al. (1998) developed a model of detailed physical land-use based on logit model to predict changes in building types and uses in street block units for the purpose of evaluating transport project's impacts and land-use regulations. But considerations regarding cost, which acts as some kind of inertia against any possible land-use change, were missing in their model. Osaragi and Kurisaki (1996) shows the effect of land use change cost in logit bid-rent model, but they use exogenously given value for cost. However, as it is very difficult to obtain cost information at lot level due to the very private nature (Wegner and Spiekerman, 1996) of such data, cost variables had been made endogenous in the present model formulation.

3. MODEL FORMULATION

In order to assess the impact of any policy intervention such as cost support system, behavior-based land-use models, such as discrete choice models are very effective. Because, if a direct regression model is used, estimated result may strongly depend on co-movements between variables observed in the sampled area and the sampled time duration. Proposed model is based on random bid-rent theory, which provides a consistent economic basis to evaluate discrete choices among various land-uses under economic policy interventions. Formation of urban land-use pattern is considered as the result of individual land owner's choice in each individual small land lot. Considering each individual land lot's characteristics in terms of its topographic condition, planning restrictions, accessibility, and neighborhood's land-use, potential future land-user make his/her assessment about expected future profit, if he/she buys the lot for any particular future intended use.

In this regard, cost, required to use a particular land lot for a future intended use, if different from its existing use, is an important consideration. In the proposed model this cost is assumed to have two components. One is cost of preparation for intended future use for example construction cost (negative effect), and the other is effect from the former use of the lot which can either be a demolition cost (negative effect) or a gain (positive effect) from the previous use if the future use is compatible in term of building, facilities and infrastructure, with the former use. Potential land-users express their own evaluation in term of the present value of future monetary flows. This value can be termed as bid-rent.

But, when they express the bid-rent to the existing land owner in the land market, cost required for land-use change must be reserved. Since potential land user's expectation also depends on uncertain factors such as future financial and economic trends, expressed bid-rent by land-user *j* for lot *n*, (U_{nj}) can be formulated as the sum of average bid-rent value V_{nj}, cost component $(1-\delta_{kj})(d_k + c_j)$ and statistically distributed error term ε_{nj}.

$$U_{nj} = V_{nj} + (1-\delta_{kj})(d_k + c_j) + \varepsilon_{nj}, \qquad (1)$$

where, d_k is effect from former land-use type *k* (negative if it means demolition cost), c_j ,is effect of intended future land-use type *j* (usually negative because it means construction cost), δ_{kj} is dummy variable which takes *1* if *k=j*, else *0*. From the definition, d_k *=0* if former land-use *k* is vacant, while, c_j *=0* if future use *j* is vacant.

If $P_n(j)$, be the probability that any land lot *n* is sold to the *j*th user in the set of possible land-users J_n and that land-use type *j* is realized, then it can be expressed as,

$$P_n(j) = \text{prob}(U_{nj} > U_{ni}, \forall i \in J_n, i \neq j). \qquad (2)$$

If the error term in equation (1) is considered to be mutually independent, and distributed in identical Gumbel distribution, following logit model can be derived.

$$P_n(j) = \frac{\exp(V_{nj} + (1-\delta_{kj})(d_k + c_j))}{\sum_{i \in J_n} \exp(V_{ni} + (1-\delta_{ki})(d_k + c_i))}. \qquad (3)$$

If observed land-use type is captured through dummy variable ζ_{nj} for land-use type *j* at land lot *n*, then logarithm of the joint probability for the observed land-use can be derived as follows,

$$L = \sum_n \sum_j \zeta_{nj} \ln P_n(j). \qquad (4)$$

If market trading price could be observed for each land lot, it might be very close to the maximum bid-rent, $\max_j U_{nj}$, and its systematic component, $\max_j V_{nj}$. As a proxy to market land price, the 'roadside price' which is used for the property tax calculation, announced each year by the taxation office, was used. Roadside price, LP_n being an average estimated price of several qualified real estate appraisal professionals, usually reflects reputation and expectation of any particular region within the city. Including such unexplained regional effect parameter θ_a, as well as a zero-mean normally distributed error term η_n, roadside price LP_n can be expressed as,

$$LP_n = \max_j V_{nj} + \sum_a \theta_a \varphi_{na} + \eta_n, \qquad (5)$$

where, φ_{na} is dummy variable showing whether land lot *n* is included in sub-region *a*. By adding the logarithm of probability for normally distributed error term, η_n to eq.(4), the following composite log-likelihood function (L') which should be maximized for estimating unknown parameters in bid-rent functions and regional dummy parameters θ_a, can be obtained.

$$L' = \sum_n \left[\sum_j \zeta_{nj} \ln P_n(j) + b\rho_n \ln \Phi[LP_n - (\max_j V_{nj} + \sum_a \theta_a \varphi_{na})] \right], \qquad (6)$$

where, $\Phi[]$ is a normal distribution probability function with zero mean and variance of σ^2, ρ_n is a dummy variable for roadside price observation in each land lot *n*. *b* is a weight determining the relative importance of the first and the second terms in the likelihood function, set as total sample number divided by number of meshes for which price information is available.

4. DATA AND MODEL ESTIMATION

For the study, land-use data was prepared in fine resolution, e.g. 100m meshes across 3 seconds of Latitude and 4.5 seconds of Longitude, in Higashi-Hiroshima City in Hiroshima Prefecture, Japan. In spite of recent rapid spatial expansion and also changes in usage of urban land in the study area, renovation or redevelopment of the historical core area of the city did not proceed. Consequently, commercial streets in the core area have lost their competing power to commercial complexes recently developed in outskirts. Recently, such problems have been reported in many local cities of Japan. This city includes 27,851 meshes, but of them those located at altitude higher than 260m, are undeveloped wooded areas. In our analysis, meshes located lower than 260m were used. At the first step of analysis, aerial-photographs taken in 1990 and 2000 were scrutinized to distinguish between built-up meshes (more than half of the area was found to be occupied by buildings or parking space) and vacant meshes (including undeveloped bare land, agricultural fields, forest, water body, road space, etc.). Then, built-up meshes were classified into sub-categories according to the main usage of the buildings, using regional paper maps published in 1992 and 2001 respectively. Sub-categories used in this research are, commercial (stores, super-markets, and office buildings), industrial (manufacturing factories), residential (detached houses and cooperative houses), and public buildings. In the model public meshes were excluded considering the fact that public usage is not determined by market competitions. So competitions between four types of land-uses, viz. commercial, industrial, residential and vacant were considered in the present model.

In order to characterize each mesh, information about accessibility, topographic conditions, planning restrictions and neighborhood's land-use were gathered. Location of national highways and major prefectural roads, JR stations and inland water bodies were obtained from the numerical map at scale of 1:2,500, published by the Geographical Survey Institute of the Japanese Government, and necessary corrections based on the aerial-photographs of the year 2000, were made. Spatial join calculation in GIS (Arc View 3.2) was applied to find the distances to these features from the centroid of each of the meshes. Using these calculated distance values, 'inverse of distance to the nearest JR station', 'inverse of distance to the nearest major highway' were prepared for each mesh. For variables of planning restrictions, dummy variables were constructed to describe whether the present land-use code permits particular type of development or not in each mesh, and whether the mesh falls within the urbanization zone of the city. The variable concerning natural disaster risks was derived from the hazard map which shows the risk of land slides and slope collapse, published in the year 2000 by the Higashi-Hiroshima City Government. Buffering function in GIS was used to prepare the variables of neighborhood's land-use. Numbers of meshes for each land-use types for the year 1990, contained in the 500m buffer from each mesh were counted to prepare variables regarding walking distance neighborhood land-use. For the sake of simplicity of calculating such variables, it was assumed each mesh is occupied by only one representative type of land-use. Roadside land price information about 311 meshes was gathered from the published document of local taxation office.

Trial using all meshes below 260m altitude, failed to achieve significant result of parameter estimation, due to strong inertia effect from the unchanged vacant meshes. Therefore, 9,192 meshes which were vacant both in 1990 and 2000 were randomly deleted, and for vacant meshes for the year 1990 a smaller number of meshes, which include same numbers of new built meshes and vacant meshes in the year 2000, was chosen. The following estimation result is based on the 3,067 sampled meshes, selected as discussed above.

Table 1 Parameter estimates of the model

Parameters of bid-rent functions (D):dummy variable	Commercial Use		Industrial Use		Residential Use		Vacant	
	estimates	t-value	estimates	t-value	estimates	t-value	estimates	t-value
Inverse distance to JR station	414.3	3.78*	-927.	-3.12*	258.3	2.61*	-	-
Inverse distance to major road	5.35	3.06*	-	-	4.54	2.74*	-	-
Public use meshes in 500m buffer	2.25	8.31*	2.25	8.76*	2.22	8.19*	2.25	8.32*
Commercial meshes in 500m buff.	2.63	18.3*	2.69	18.5*	2.63	18.4*	2.64	18.3*
Industrial meshes in 500m buff.	-1.32	-10.3*	-1.23	-9.63*	-1.39	-10.9*	-1.41	-11.0*
Residential meshes in 500m buff.	0.45	3.65*	0.35	2.82*	0.46	3.73*	0.41	3.28*
Permitted use in zoning (D)	2.22	10.5*	2.77	9.65*	0.97	6.07*	-	-
Designated as Urbanization Area (D)	-	-	-	-	-	-	-0.92	-4.9*
Proximity to Disaster Prone Area(D)	-	-	-	-	0.62	3.78*	-	-
Constant	5.27	3.32*	1.43	3.52*	1.69	6.42*	-	-
Parameters for land-use change	estimates	t-value	estimates	t-value	estimates	t-value	estimates	t-value
Effect of future land-use	-3.71	-9.43*	-7.80	-4.9*	-2.64	-10.1*	-	-
Effect of former land-use	-0.03	-11.8*	6.04	3.81*	1.48	4.61*	-	-
Land Price Observation Parameters	estimates	t-value					estimates	t-value
Around Saijo Station(D)	59.32	17.6*	Land Adjusted Project Area(D)				91.01	70.2*
Around City Office (D)	84.52	26.8*	Jike Area(D)				86.52	35.6*
Doyomaru Area (D)	78.63	24.9*	Misonou Area (D)				53.07	24.0*
Variance	2.16×10^{-3}		(37.96*)					
Initial Likelihood	-29924	Likelihood Ratio		0.5	Sample Size		3067	
Final Likelihood	-15017	Proportion of Correct Predictions					66%	

*:1 % level of significance, Unit of the parameters :10^3yen/m^2(besides Variance)

Table 1 shows the parameter estimates and t-values; many of them have expected signs and are statistically significant. For commercial and residential uses, accessibility to JR station and major roads were found to be positive significant. Permission by zoning system was found to raise bid-rents for all land-use categories significantly. Industrial use was found to be more strongly affected by zoning permission compared to commercial and residential uses. Urbanization Area designation was found to decrease the possibility of vacant use. For all land-use categories, public, commercial and residential land-uses in the neighborhood showed positive effects on the bid-rent, but industrial use in the neighborhood showed negative effects. Proximity to the Natural Disaster Prone Area (NDPA) was found to have positive estimate for residential use which is contradicting to intuition. However, we could understand the reason for it; NDPA was defined as the area where certain number of houses is located under the possible risk. According to this definition, residential use was always observed in NPDA, which yielded the positive estimate value for this parameter.

All parameter values for preparation cost for future use in Table 1 were found to be negative and statistically significant. This suggests reduction of bid-rent due to probable construction cost required to change land use from their existing use. Among the three categories, commercial use requires such cost two times more than industrial use and three times more than residential use. On the other hand, parameter values for gain from former use, in case of industrial use were negative significant, while for residential and commercial uses were positive significant. This suggests, in case of changes from either residential or commercial land-uses, to the other and also to industrial use category, some positive gain can be expected. This positive gain is the reuse value from the existing buildings or infrastructure already in place. However, negative former use cost value for industrial use suggests, changing of industrial land-use to other categories will always require some cost which can be termed as demolition cost for industrial buildings. Likelihood ratio (0.5) and proportion of correct prediction (66%), as can be observed from Table 1, suggest sufficiently high reproducibility power of the model. Using estimated parameter values, land-use simulation has been done for the study area and predicted land-use has been found to be reasonably consistent to the observed land-use.

5. SIMULATION RESULTS

To assess the effect of cost support policy, simulation was carried out for 12,713 meshes out of 27,851 meshes in the study area, which are under 260 m elevation. 367 public-use meshes were kept out of simulation considering the fact that public usage is not determined by market competitions. So land-use changes among four categories viz., commercial, industrial, residential and vacant were observed in 12,346 meshes in the study area. Three scenarios were tested, viz., without any support (scenario1), with flat rate support of average construction cost (4,713 yen / m^2) for all three build able uses ,i.e., commercial, industrial and residential among 4 above categories (scenario 2) and with flat rate support of the estimated construction cost for each of the three build able uses (scenario3). Figure 1 shows the comparison of three above mentioned scenarios in case of 5% cost support for scenarios 2 and 3.

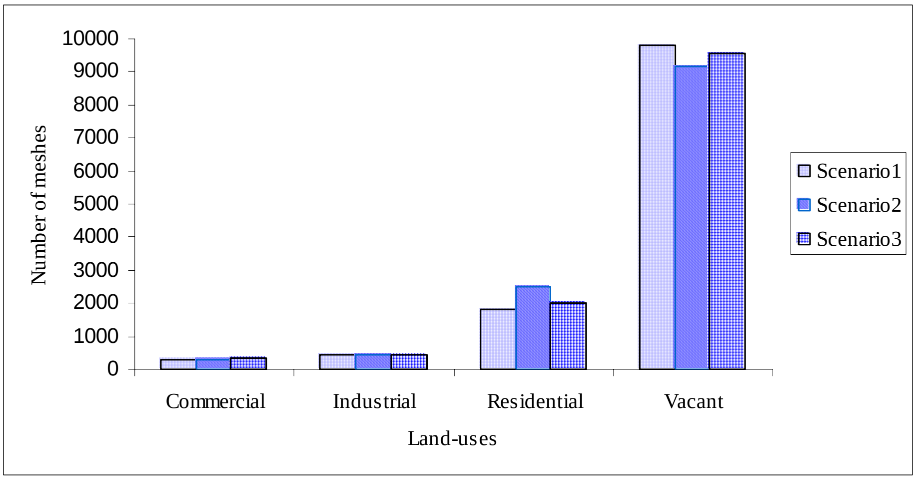

Figure 1: Comparison of predicted land-uses under three simulated scenarios

Increase in total numbers of residential and industrial meshes from scenario1 were observed in scenarios 2 and 3. The increase was found higher in case of scenario 2. In commercial use category, number of commercial meshes remained same in scenario 1 and scenario 2 but increased in case of scenario 3. Total number vacant meshes decreased in case of both scenarios 2 and 3. The decrease was higher in case of scenario2. Since no support was provided to vacant meshes for remaining vacant, total number of vacant meshes decreased, causing increase in built-up meshes. As can be observed from Table 1, cost of future use is much higher for commercial use; therefore, flat rate support of average construction cost (scenario 2) could not increase the numbers of meshes in commercial category. Instead a flat rate, support of different construction cost for different category (scenario 3) could increase the commercial bid-rent for each mesh and could make commercial use winner in the competition with other uses resulting higher numbers of commercial meshes.

Table 2 shows the changes among various land-uses between scenario1 and scenario 2. It is evident from Table 2 that meshes in all three categories (commercial, industrial, residential) remained same in both scenario1 and scenario 2. The increase in total number of industrial and residential meshes in scenario 2 was mainly due to the changes of vacant meshes to either industrial or residential meshes.

Table 2: Land-use change matrix between scenario 1 and scenario 2

Land-use with support (scenario2)	Land-use without support (scenario1)					
	Land use	Commercial	Industrial	Residential	Vacant	Total
	Commercial	272	0	0	0	272
	Industrial	0	417	0	22	439
	Residential	0	0	1837	640	2477
	Vacant	0	0	0	9158	9158
	Total	272	417	1837	9820	12346

Table 3: Land-use change matrix between scenario 1 and scenario 3

Land-use with support (scenario3)	Land-use without support (scenario1)					
	Land use	Commercial	Industrial	Residential	Vacant	Total
	Commercial	272	6	70	0	348
	Industrial	0	411	1	18	430
	Residential	0	0	1766	237	2003
	Vacant	0	0	0	9565	9565
	Total	272	417	1837	9820	12346

Table 3 shows the changes of different land-uses between scenario 1 and scenario 3. Land use changes were observed across industrial, residential and vacant categories. Out of 417 industrial meshes in scenario 1, 411 remained industrial and 6 became commercial. Among 1,837 residential meshes in scenario 1, 1,766 remained residential, 1 became industrial and 70 became commercial in scenario 3. Among 9,820 vacant meshes in scenario 1, 9,565 remained vacant, while 18 became industrial and 237 became residential. Commercial meshes in scenario 1 remained commercial in scenario 3 also.

Figure 2 shows the land-use changes from scenario 1 with the increase in amount of support provided in scenario 2. This figure shows that no changes in the number of commercial meshes were observed with the increase in the amount of support. Industrial meshes increased up to 15% support and then got stabilized. After this point, remaining vacant meshes do not possess suitable conditions for residential use. But further support forced those meshes to become residential. At 35% level of support all vacant meshes became built up. In this saturated situation, residential use occupied most (94%) of the built-up meshes, while commercial and industrial uses occupied 2.2% and 3.8% share of the built-up meshes respectively.

From this observation it can be concluded that, in case of scenario 2 this support mechanism works at margin and favors looser instead of winner in the competition between different land-uses to get realized in a particular mesh. As a result, elite class of commercial meshes, which are insensitive to such cost supporting mechanism, is observed. These meshes have commercial bid-rent value so high that no supporting mechanism to other uses can make them win over commercial bid-rent values in this elite class of commercial meshes.

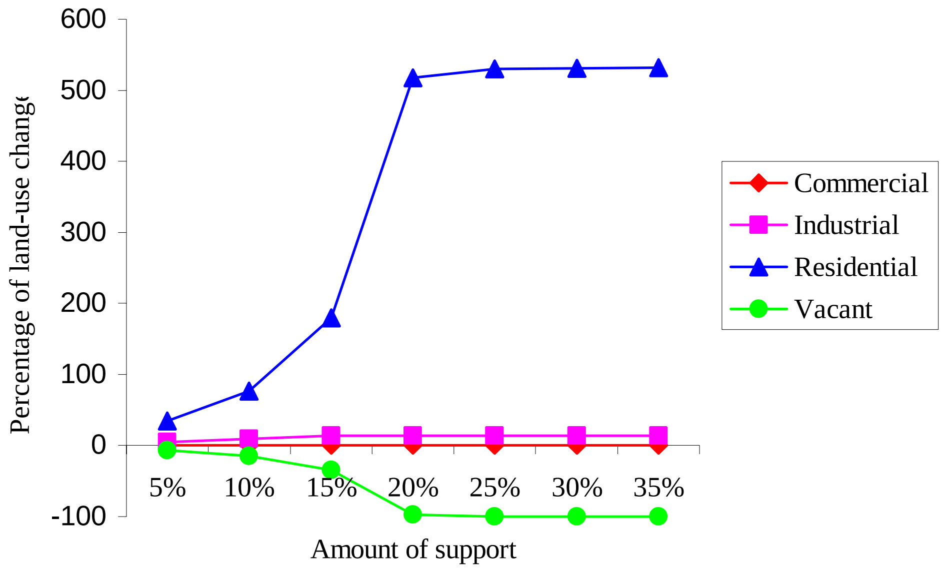

Figure2 Effect of increase in flat rate support for scenario 2

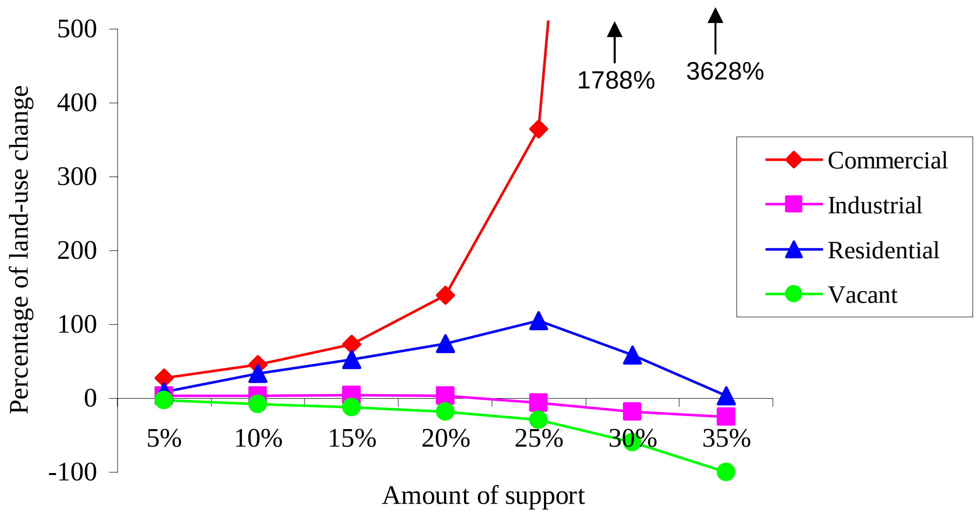

Figure3 Effect of increase in flat rate support for scenario 3

Figure 3 shows the land-use changes from scenario1 with the increase in amount of support provided in scenario 3. Since support is provided at a flat rate of the estimated construction cost for each type of build able land-uses, and as construction cost for commercial land-use is much higher than other two types as evident from Table1, number of commercial meshes increase with the increase in the rate of support. Number of industrial and vacant meshes decrease while number of residential meshes increase up to 25% support level and then decrease due to replacement residential meshes by commercial use due to higher support provided to commercial use. All meshes were observed to become built-up at 35% support level in this case also. At this saturated situation commercial use occupied most of the (82%) of the built-up meshes, contrasting to the findings of scenario 2, where residential meshes occupied most of the built-up meshes.

6. CONCLUSION

Statistical model with endogenous cost variables, developed in this research, have been found effective in explaining effect of cost support policies on land-use changes for the study area. In simulation no external control total had been used and only simple flat rate support to bid-rents for all three built-up land-use categories was tested. In real world evolution of urban spatial pattern is subject to many spatial constraints and to make construction cost support effective, differential treatment of cost support according to the planning goal of the city would be required. In future, issues such as differential cost support mechanism considering spatial constraints will be addressed in our modeling effort.

REFERENCES

Landis, J.D., Imagining Land Use Future: Applying the California Urban Futures Model, *Journal of the American Planning Association*, 1995, Vol. 610, pp. 6-11.

Lowry, I.S. A Model of Metropolis. RM-4035-RC. The RAND Corporation, Santa Monica, California, 1964.

Miyamoto, K., Kitadume, K., A land –use model based on random utility/rent-bidding analysis (RURBAN), Selected Proceedings of the fifth World Conference on Transport Research, IV,1989, pp.107-121.

Miyamoto, K., et al. A model of Detailed Physical Landuse Patterns for Environmental Considerations, Paper submitted to *the 8th World Conference on Transport Research*, Antwerp, Belgium, 1998.

Okumura, M., and Haque, S.M., Land-use model based on observed land price and detailed geographic data, *City planning review*, 2002,Special Issue, pp. 103-108 (in Japanese).

Osaragi, T., and Kurisaki, N., A utility model of lamd-use transition probability and its application, Theory and Applications of GIS, 1996, Vol.4,No.2, pp.7-14.

Putman, S.H., EMPAL and DRAM Location and Land use Models: An Overview. Paper distributed at the Transportation Model Improvement Program's Land Use Modeling Conference, Dallas, Texas, February,1995, pp. 19-21.

Spiekerman, K., and Wegener, M., Freedom from the tyranny of zones, in *Spatial models and GIS: new potential and new models*, edited by A S Fotheringham, M Wegener; Taylor and Francis, London, 2000.

Waddell, P., An Urban Simulation Model for Integrated Policy Analysis and Planning: Residential Location and Housing Market Component of UrbanSim, *8th World Conference on Transport Research*, Antwerp, Belgium, 1998.

Wegener, M., and Spiekerman, K., The Potential of Microsimulation for Urban Models, in *Microsimulation for Urban and Regional Policy Analysis*, Clarke, G.P. (ed.), Pion, London, 1996. pp. 149-163.

Wegener, M., GIS and spatial planning, *Environment and Planning B: Planning and Design Anniversary Issue*, 1998, pp. 48-52.