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SIMULATION OF LAND-USE CHANGES FOR STRATEGIC URBAN MANAGEMENT WITH A GIS BASED STATISTICAL MODEL

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Abstract: A statistical model using physically observable (land-use and land character) variables and land price information has been proposed in this research to simulate intra-city land-use changes. Geographic Information System (ArcView 3.2) was used to prepare detail database for each of the100m meshes of the study area, Higashi-Hiroshima City of Japan. Considering each mesh's characteristics in terms of its topographic condition, planning restrictions, accessibility, and neighborhood's land-use, four different bid-rent functions for four different land uses, viz., industrial, commercial, residential and vacant were constructed. A random bid-rent model to describe the competitions between the above mentioned uses was developed using both physical characteristics and land price information. Using two types of assignment rules viz., deterministic and probabilistic, CA like simulation procedures were used to generate future predicted land use pattern. Generated patterns were compared with the observed land-use pattern. Two indices for spatial concentration for commercial and residential use have been proposed. Besides, an infrastructure need index to estimate infrastructure requirements for new built-up areas has also been proposed. Changes in indices over time and their relationship with the generated patterns were also analyzed and discussed in this research.

Keywords: land-use model, GIS, strategic urban management

1. INTRODUCTION

Both at local and national levels, a major trend that has been observed recently is the shift from centralized government systems to more decentralized ones (Mawhood, 1993). Implication of this shift in the context of urban management is the emergence of a planning process which is more dynamic and responsive to the hopes and aspirations of the urbanites. Traditional 'Master Planning' type planning approach, which is static and authoritarian in nature, clearly falls short of such requirements. Besides, the long time and strict regulatory controls in terms of zoning regulations, needed to materialize a certain type of land use with certain prescribed density in certain place, are very unpopular and at times, unnecessary in the rapidly changing context of present day cities. From city management point of view, as far as infrastructure provision is concerned, it may be wasteful if heavy initial investment is made in some place which subsequently looses its attractiveness and fails to attract desired type of land use with desired density within a stipulated time frame. Management efficiency is also reduced if small initial investment in infrastructure and a long interval phasing for infrastructure provision is made, as it will exert too much pressure on existing infrastructure, and will result a very low level of service making people unhappy. To deal with rapidly changing environment of cities, strategic planning approach which is more oriented towards identification of problems or objectives and formulation of effective and timely means of bringing available resources to resolve the problems or implement the objective, is an useful and effective alternative. Such planning approach, as advocated by Solesbury (1975), should have broader policy content and should not be just concerned with land allocation, but also with the form of development, land use and transport relations and the quality of the physical surroundings. Clearly strategic planning for cities requires disaggregated approach of model building for land use prediction, which is capable of taking account of the heterogeneity that exists among city’s land uses and spatial interaction among different land uses that surround a particular land parcel or land-use type and also which should be responsive to the various policy implications.

History of urban land-use modeling dates back to early 1960s. Both operational and economic models to predict urban spatial pattern started at about same time. Initially, both types of such models were mono-centric and representation of space had been very relative and abstract. In operational models, until very recently, urban land-use patterns were generated taking a reductive approach (breaking whole to parts) of allocating exogenously decided control totals of various land-uses to various urban zones. In urban economic models, urban spatial pattern has been tried to explain in terms of economic notions such as bid rents, calculated assuming a single centre such as CBD in urban setting. With the increased availability of geographic data at relatively fine level and with the advent of GIS and remote sensing technology, new situation can now be observed in urban land-use modeling arena. In case of operational modeling, Cellular Automata (CA), which is a synthetic approach (from parts to whole) of model building, has been very popular now. But CA is still far from perfect because formulation of transition rule in CA modeling does not have sound theoretical back ground and therefore, it is difficult to assess any policy implications on CA generated urban patterns. In urban economic modeling arena, key shift is the consideration of the interactions among various economic entities (land uses) distributed in an urban setting. But to generate equilibrium situation most of the heterogeneities among the entities have been compromised and as a result, at equilibrium resulted land use pattern is very gross and aggregated.

To facilitate strategic urban management, it is therefore, needed to develop land-use modeling technique which integrates operational techniques and urban economic theories together in a participatory set up and also can explain urban spatial pattern with theoretically convincing hypothesis. It has been assumed in this research that urban spatial pattern is an accumulated result of land use changes in each of small land lots. As expected utility for using a particular land lot for a particular purpose depends, among other things, on the existing land uses of surrounding land lots, so there is a network of interactions among different land uses of such small land lots within a city. Spatial agglomeration or clustered structure may emerge from such interactions among small-scale land uses. Besides, for strategic urban management prediction of relative distributions of various land-uses with in a city is needed as these relative distributions fundamentally determine the volume of infrastructure required to support the activities in the city. Such prediction needs to be developed by adapting a disaggregated approach of modeling interactions among fine level land-uses within a city considering the need for basic indices required for infrastructure management.

2. SCOPE AND PURPOSE OF THE RESEARCH

Purpose of this research is to build a model for assessing the character of predicted land-use in terms of land-use concentration and to estimate future infrastructure requirements in order to facilitate strategic urban management. Here, in case of infrastructure, scope was limited to only linear type of infrastructure such as roads, electricity line, water supply and sewerage lines. In case of land-use characters, concentration of commercial, residential, mixed use of commercial and residential and total built-up area, have been considered.

It is assumed that the city's spatial structure is formed by the interactions among each of individual small land lots. Several characteristics of any particular land lot determine the future profit or advantage for particular type of land usage, which can be evaluated by bid rents as present value. In this research, considering each individual mesh's characteristics in terms of its topographic condition, planning restrictions, accessibility, and neighborhood's land-use, four different bid-rent functions for four different uses, viz., industrial, commercial, residential, and vacant, were constructed. As a result of competition among above mentioned land uses in a particular mesh, the highest bid rent can be observed as land price, and the land-use having highest bid rent is realized in that particular mesh. A combined model of Random bid-rent logit and land price regression has been developed in this research.

Using two types of assignment rules viz., deterministic and probabilistic, CA like simulation procedures were used to generate future predicted land-use pattern, under the constraint of observed number of meshes for different types of land use in 2000 as control total. The simulation process resulted in different distributions of built-up meshes generating different spatial patterns for each of the successive iterations. Generated patterns were compared with the observed land-use pattern by concentration indices for commercial land use and residential land use. Finally, expansion requirement for infrastructure were estimated by infrastructure need index which, is the difference between summation of the distances between centroids of built-up meshes for each iteration and the summation of distances between centroids of the nearest built-up meshes for the base year1991.

3. REVIEW OF URBAN LAND-USE MODELS TO DATE

After the original formulations of the mono-centric agricultural land-use theory, many mono-centric economic land-use models (Alonso, 1964; Muth, 1969; Mills, 1967) began to emerge in the urban economics literature. Being mono-centric and having abstract and relative representation of space, these models fail to incorporate spatial interaction processes and clearly fall short of the requirements for strategic planning. Most of the recent urban economic models (Fujita et al., 1999; Krugman 1996; Anas and Kim 1996) focused on explaining the formation of urban spatial structure as endogenous process which is the result of interaction among various actors distributed in space. In order to explain the equilibrium situation most of the heterogeneity of the variables have been ignored in these models, and as a result at equilibrium, resulted land-use patterns are quite abstract. On the other stream, geographers and natural scientists developed numerous spatially explicit cell based empirical models with the advent of GIS and remote sensing based technologies (e.g., Anderson and Souleyrette, 1996; Batty, Fotheringham and Longley,1989; Berry et al., 1996; Clarke, Hoppen and Glydos, 1997). Some hybrid models considering both economic (population density etc.) and natural variables (slope, soil, elevation) have also been developed (Ives, Turner and Pearson, 1998). But these models are simply grid based Markov models.

In operational field, Lowry's Model of Metropolis (1964) based on the assumption that the place of basic employment determines the place of residence, is considered to be the pioneer. Many operational urban simulation and land-use transportation interaction models of Lowry derivative types are in use since early 1970s. These models have land-use components, in a sense that they allocate housing or employment to various destination zones. Of them the Disaggregated Residential Allocation Model (DRAM) and the Employment Allocation Model (EMPAL) model are claimed to be "most widely applied models" (Putman, 1995) of their types. The MEPLAN model (Echenique et al., 1990) was constructed using three economic concepts, i.e. input-output model, price function and random utility. The coefficients of the input-output model are used to calculate prices in an elastic form to represent land allocation within zones. Random utility is used to represent an explicit spatial system where households and firms decide where to live and locate in a utility maximization or a cost minimization framework within specified constraints. This allows market land prices be considered in the model explicitly. The METROSIM model of Anas (1994) embodies the discrete choice method with economically specified behavior and a market clearing mechanism. The model iterates between three markets, namely, labor market (job assignment), housing and commercial space market (location equilibrium), and the transportation service market (equilibrium of transportation flows). These equilibria markets are defined through seven sub-models or sectors. UrbanSim (Waddell, et al, 2001) employs a comparatively fine resolution with grid size of 150mX150m, much owing to the recent progress of GIS technology and detailed geographical data. UrbanSim takes two key input from external model system, a macro economic model to predict future macroeconomic condition such as population and employment by sector, and a travel demand model system to predict travel conditions such as congested times and composite utilities of travel between zones. Independent variables used for calculating probabilities household and employment location choices, are related to the characteristic of the sites but do not consider the characteristics of adjacent sites.

As a way to include the effects from surrounding areas into urban modeling, Cellular Automata technique gained popularity. Cellular automata (CA) have been applied to the simulation of wide range of urban phenomena. CA models have been used to study land-use dynamics (Cecchini1996, Webster and Wu 1999a, b, White and Engelen 1993); poly-centricity (Wu 1998); location analysis (Benati 1997); urbanism (Sanders, Pumain, Mathian, Gu´erin-Pace and Bura 1997); and urban growth and sprawl (Batty 1999, Clarke, Hoppen and Gaydos 1997). The popularity of urban CA models owes much to several advantageous properties that CA offers as a synthetic approach of model building. Besides, being more participatory in nature and having considerations regarding the effect of neighborhood, CA is very appealing to the modelers intending to model spatial interaction processes. CA depends on the interactions of entities (cells having different states) based on intuitively understandable behavioral rules, rather than performance functions. Such behavioral rules are generally decided by the researchers. It is completely wrong however, to assume that cities can be evolved without intervention or interaction of some processes generated at macro level (regionally, outside the influence of local cells). These factors, in some researches have been considered in terms of formulating constraints. However, formulation of such constrains violates one of the basic assumptions regarding unconstrained nature of formal CA. Though CA has the potential as tool in simulation of urban patterns but it is very slow to adopt explicitly geographic or urban theory as a basis for transition rule formulation, which is the core of such kind of simulation.

4. MODEL FORMULATION

In order to make model operational, policy interventions such as land-use control, investment in infrastructure, land-use tax must be taken into consideration. It is unadvisable to express these influences with a direct statistical model, because estimated result may strongly depend on the particular co-movements between variables observed in the sampled area and the sampled time duration. Alternative to such unstable statistical modeling, more stable and transferable behavior-based modeling is in practice now. Among several approaches, discrete choice model seems to be the most applicable, if 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 land-user make his/her assessment about expected future profit, if he/she buys the lot for the use he/she intending to do. They express their own evaluation in term of the present value of future monetary flows to existing land owner in the land market. That value is called bid-rent. Because their expectation also depends on uncertain factors such as future financial and economic trends, bid rent by land-user *j* for lot *n*, (U_{nj}) is captured as the sum of average value V_{nj}, and statistically distributing error term ε_{nj}.

$$U_{nj} = V_{nj} + \varepsilon_{nj} \tag{1}$$

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

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

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

$$P_n(j) = \frac{\exp(V_{nj})}{\sum_{i \in J_n} \exp(V_{ni})} \tag{3}$$

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

$$L = \sum_n \sum_i \delta_{ni} \ln P_n(j) \tag{4}$$

If market trading price could be observed for each land lot, it might be very close to the maximum bid rent; $max_k\ U_{nk}$, and its systematic component, $max_k\ V_{nk}$. 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, road side price LP_n can be expressed as,

$$\mathrm{LP}_n = \max_j(V_{nj}) + \sum \theta^a \varphi_n^a + \eta_n \tag{5}$$

By adding the logarithm of probability for normally distributed error term, η_n to eq.(4), 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.

$$L' = \sum_{n} \left[\sum_{i} \delta_{ni} \ln P_n(i) + bd_n \ln \Phi[LP_n - (\max{}_i V_{ni} + \sum_{a} \theta^a \varphi_n^a] \right] , \tag{6}$$

where, $\Phi[]$ is a normal distribution probability function with zero mean and variance of σ^2, d_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 / number of price observations.

5. DATA AND MODEL ESTIMATION

In 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. This city includes 27,851 meshes, but of them those are located at altitude higher than 260m, are undeveloped wooden area. In the following 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, e.t.c.).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, residential (detached houses and cooperative houses), industrial (manufacturing factories), commercial (stores, super-markets, and office buildings) and public buildings. Figure 1 shows the observed land-use pattern in year of 2000.

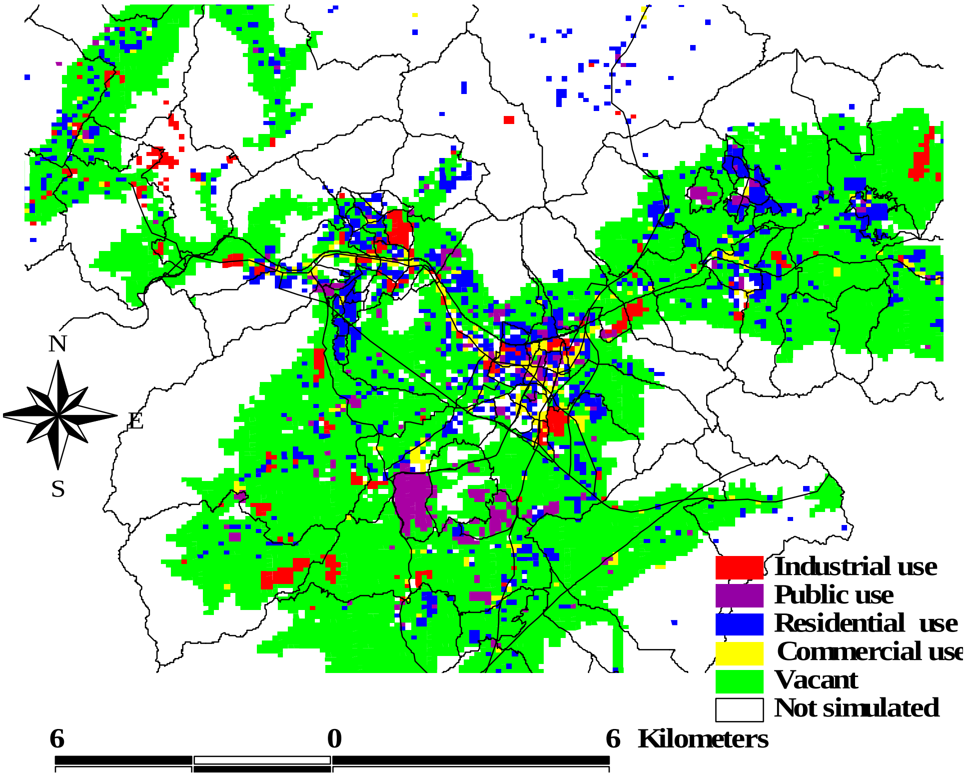


Figure 1: Observed land-use pattern of Higashi Hiroshima city for the year of 2000

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 1:2500, 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', and a dummy variable explaining whether the mesh is with in 100m of 'water body', 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 urbanized zone of the city. The variable concerning natural disaster risks was derived from the hazard map showing the risk of land slides, slope collapse published in 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 of 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 type of land use. Roadside land price information about 311 meshes was gathered from the published document of taxation office. 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. industrial, commercial, residential and vacant were considered in the present model. Trial using all meshes of those four types below 260m altitude, failed to achieve significant result of parameter estimation, due to the large effects from the unchanged meshes. Then 9,192 meshes were randomly deleted from the meshes which were vacant both in 1990 and 2000, and a smaller sample which includes similar numbers of new built meshes and un-built meshes in vacant meshes in 1990 was chosen. The following estimation result is based on the 3,068 sampled meshes, selected as discussed above. Table 1 shows the parameter estimates and t-values; many of them have expected sign and are statistically significant. Likelihood ratio and fit ratio proves that reproductive power of the model is sufficiently high. According to the parameter estimates, the following observations can be made.

1) For commercial and residential land-use, positive estimates were derived for inverse of distance to the nearest JR station, which shows that these land-uses appreciate the accessibility to the station.
2) For all land-use types, number of commercial meshes and public building meshes inside 500m buffer had positive parameter estimates, suggesting that the convenience offered by these facilities are positively evaluated in bid rent calculation.
3) Number of residential meshes around had positive effect on all type of bid rent functions. This effect possibly reflects the availability of basic infrastructure that has already been built for the developed land, as well as the potential marketing power for commercial activities.
4) Land-use restriction had positive significant effects on all land-use types. Urbanized area designation has significant negative estimate on vacant land. It authenticates that the restricting any area for particular designated use effectively restrain the development process.

Table 1 Parameter estimates of the model

	Industrial Use			Residential Use			Commercial Use			Vacant		
Parameter name (D is Dummy variable)	Estimate	t value		Estimate	t value		Estimate	t value		Estimate	t value	
Inverse Distance to nearest station	-905.3	-3.1	**	242.1	2.5	*	391.3	3.6	**	-	-	
Inverse Distance to nearest road	-3.88	-1.2		0.12	0.3		0.35	0.7		-	-	
No. of public use meshes within 500m buffer	2.28	8.3		2.24	8.2	**	2.28	8.3	**	2.28	8.3	**
No. of commercial meshes within 500m buffer	2.82	19.9	**	2.77	19.8	**	2.76	19.7	**	2.76	19.6	**
No. of residential meshes within 500m buffer	0.36	2.8	**	0.46	3.7	**	0.45	3.6	**	0.4	3.2	**
No. of industrial meshes within 500m buffer	-1.29	-10.1	**	-1.44	-11.3	**	-1.38	-10.8	**	-1.46	-11.4	**
Proximity to water surface(D)	-0.02	-0.1		-0.01	-0.1		0.21	1.4		-	-	
Proximity to disaster prone area(D)	-0.19	-0.5		0.55	3.1	**	-0.23	-0.6		-	-	
Planning regulation(D)	2.76	9.5	**	0.97	6	**	2.26	10.7	**	-	-	
Different landuse than 1990(D)	-3.28	-11.8	**	-1.1	-5.5	**	-1.97	-7.7	**	-	-	
Constant	1.01	3	**	0.2	0.9		-0.63	-2.2	*	-	-	
Urban area(D)	-	-		-	-		-	-		-0.93	-4.8	**
Not Vacant in 1990(D)	-	-		-	-		-	-		-1.59	-6.1	**
Rent value Functions												
Variance	0	38.7	**									
Around Saijo Station(D)	59.69	17.6	**									
Around Saijo Showa(D)	81.55	26.2	**									
Doyomaru(D)	79.91	25.2	**									
Central Saijo(D)	91.27	70.1	**									
Jike(D)	88.07	36.4	**									
Misono(D)	53.08	24.2	**									
Initial Likelihood	-30014											
Final Likelihood	-15069											
Likelihood Ratio	0.5											
Hit rate	67.10%											
Sample size	3068											

*:5% level of significance
**:1% level of significance

6. SIMULATION PROCEDURES AND METHOD OF COMPARING RESULTS

Logit model outputs the probabilities for each type of land use for each of the meshes. Two types of assignment procedures; deterministic and probabilistic, were used in simulation to get predicted pattern of city in this study. In deterministic assignment, land use having highest bid rent value, i e., the winner of the competition among different uses, was assigned to that mesh. No consideration was made in such assignment procedure to other land uses, even when the probability of the next one was almost same as the first one. Besides, in real world the development pattern is not always very deterministic in nature.

To take account of the random nature that development might follow, probabilistic assignment procedure was considered. In probabilistic assignment, random numbers between 0 and 1 were generated for each of the meshes. Generated random numbers were compared with calculated probabilities for each type of land uses for each of the meshes and assignment was made to the use which best corresponds to the random number. In the model, bid rent functions include the effect of the surrounding land uses, so in simulation the surrounding situation was updated by the first round predicted land use and the process was repeated for subsequent iterations. These iterated simulations were able to take positive agglomeration effect into account. However, if this iterative simulation is applied without control total, build-up meshes were observed to increase much rapidly than the reality, because of the positive feedback effects in simulation. To avoid such unrealistic result, control total were imposed in the simulation process; the numbers of each types of built-up meshes in each iteration were fixed to be equal to numbers of developed meshes for observed situation i.e, for the year 2000.Because of the imposing of such control total, land uses shift their relative position but total development remains constant across the iterations. This allows us to discuss our prediction results in terms relative shifts of land uses which generate different spatial pattern of the city after each of the iterations.

Till the date, cross matching of the cells is widely used in order to compare the results of urban simulations. But when simulation is done under some constraints e.g., control total in our case, cell by cell comparison seems not very realistic. From the strategic management point of view, exact lot by lot comparison is not necessary also. Index based comparison procedure was proposed in this research which, we believe, can better explain the changes in spatial pattern of the city's land use and also capable of addressing the need of strategic urban management. Commercial and residential use concentration indices were defined as the number of commercial and residential meshes within 500 m of each of the respective types of meshes. The purpose of proposing such indices is to observe the effect of spatial concentration pattern over successive iterations of the model, which was done by looking at the shift of cumulative distribution curves of different concentration indices in successive iterations from observed distribution. In the model neighborhood land-use character of each mesh was characterized by some variables calculated within 500m considering the existing studies regarding walking limit distance. Same distance was considered in the calculating the indices also. Finally, infrastructure need index was proposed to estimate the need for infrastructure expansion corresponding to the spatial pattern. In this case, distances between all built up mesh centroids in kilometer from the base situation i,e, from all built-up mesh centroids for the year 1991, were calculated using spatial join function of GIS. The assumption in this case was, existing built-up areas had necessary infrastructure already provided and additional network is to be added to the frontiers of existing network. Therefore, summation of distances between centroids of predicted built-up and existing built-up meshes would give the requirement for additional infrastructure.

7 RESULTS AND DISCUSSION

7.1Deterministic Assignment

Figure 2 shows the simulated pattern of the land-use, which seems more concentrated than the observed one, shown in figure 1

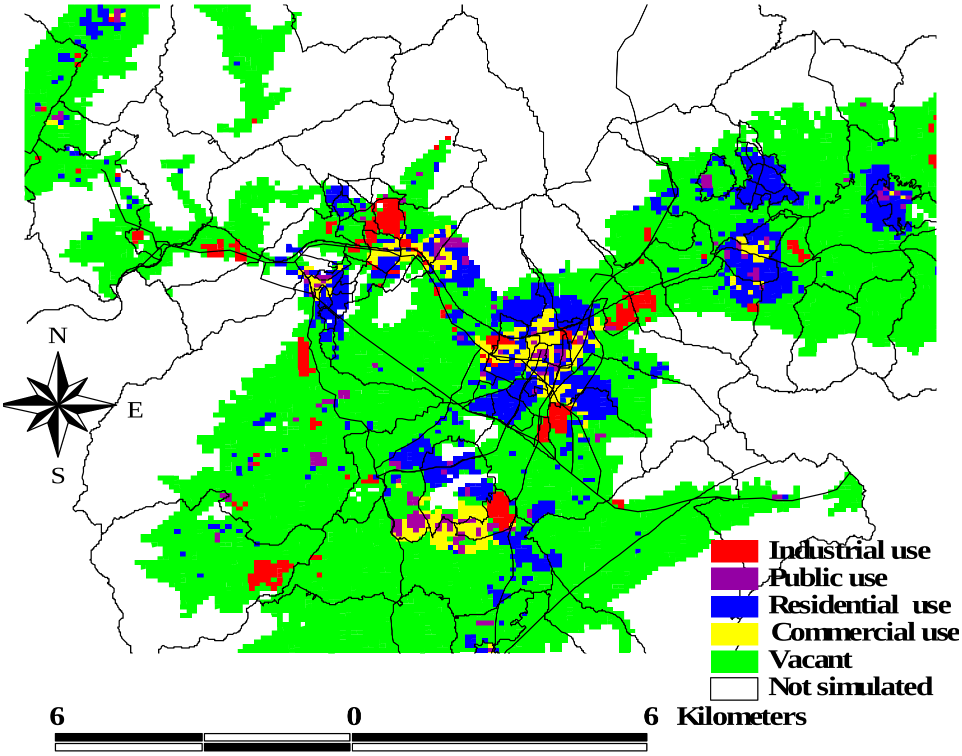


Figure 2 Land-use patterns simulated by deterministic assignment

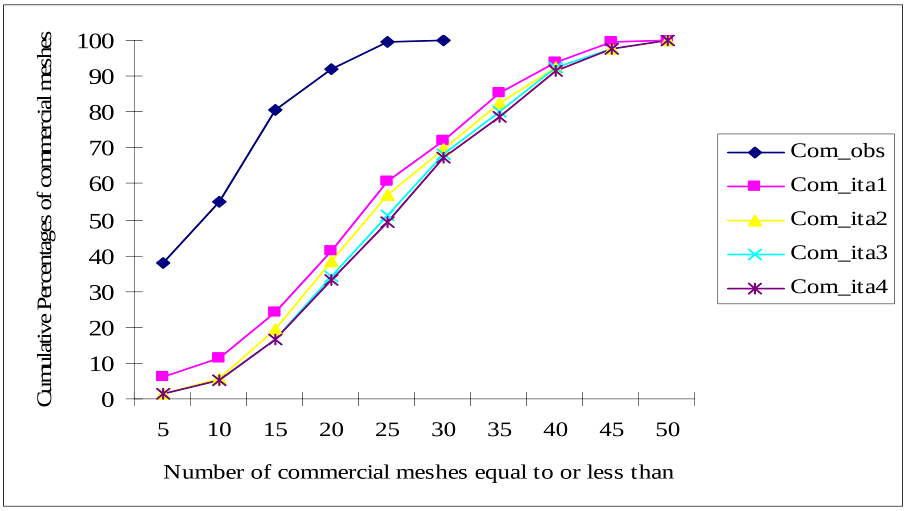


Figure3 Cumulative distribution of commercial use concentration index in deterministic assignment

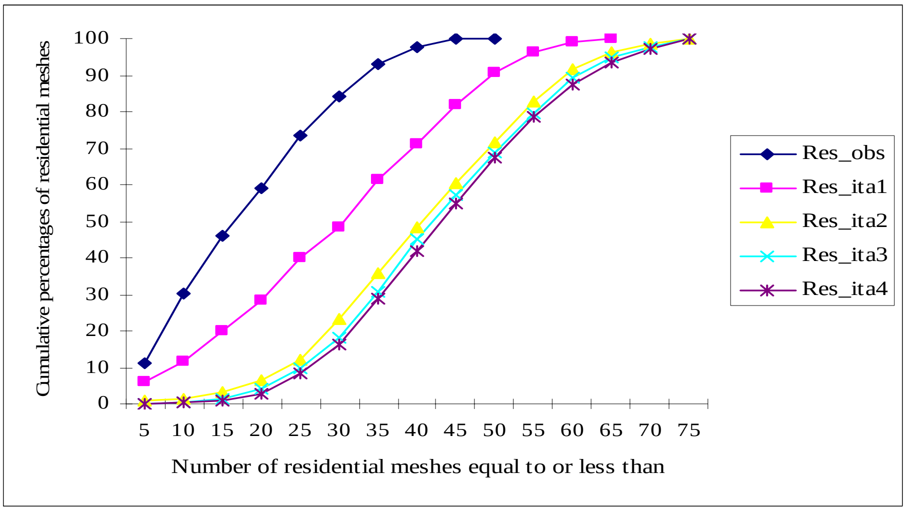
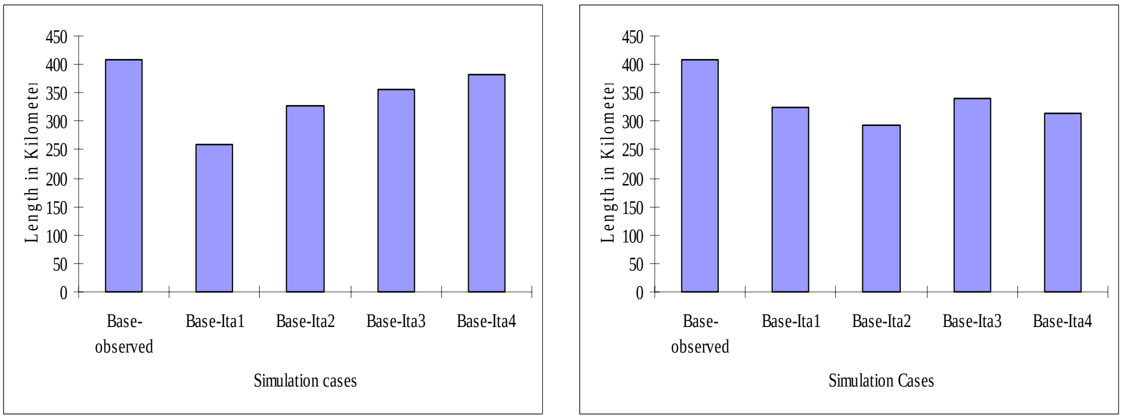


Figure 4 Cumulative distribution of residential use concentration index in deterministic assignment



Deterministic

Probabilistic

Figure 5 Infrastructure need index in deterministic and probabilistic assignment

In case of deterministic assignment, as evident from Fig 3 and 4, both commercial and residential cumulative distribution curves shift downward from observed distribution in each of the successive iterations, suggesting incremental concentration of these land-uses. Our prediction results always over estimated the concentration trend. Reasons might be, in real world there exists a sort of inertia which prohibits land use to concentrate faster following a strict deterministic rule. Time interval which is considered 10 years in this research, might be a bit longer, as in real world, land use change might take place at a slower rate than what has been envisaged in our study. Political intervention can break this inertia through land-use policies to encourage concentrated spatial pattern for the city. In formulating such policies, instead of making strict zoning regulations, fiscal policy which can be evaluated through our model, would be a better option. However, after the second iteration, curves become closely spaced among themselves which indicates some level of saturation. Commercial concentration index attains saturation level faster than residential concentration index which suggests a trend of commercial development close to other commercial areas, taking positive agglomeration effect of economy into consideration. But it can be observed from figure 5(left) that, there is an incremental increase of infrastructure need index in each of the successive iterations. Our intuitions suggest that there should be an inverse relationship between land-use concentration and infrastructure need. As infrastructure need index was calculated considering the base situation of 1991 it seems that concentration of built-up area took place to fill up the vacant places with in the built-up area of base year, where there had been no infrastructure in the base year. As a result infrastructure need index shows increasing up-ward trend with the increasing concentration. However, under no circumstances this index crossed the level of base to observed situation. This indicates that simulated land-use patterns are always more concentrated than observed situation.

7.2 Probabilistic Assignment

Figure 6 shows the land-use pattern predicted by probabilistic assignment rule, which seems less concentrated than the deterministic assignment shown in Figure 2

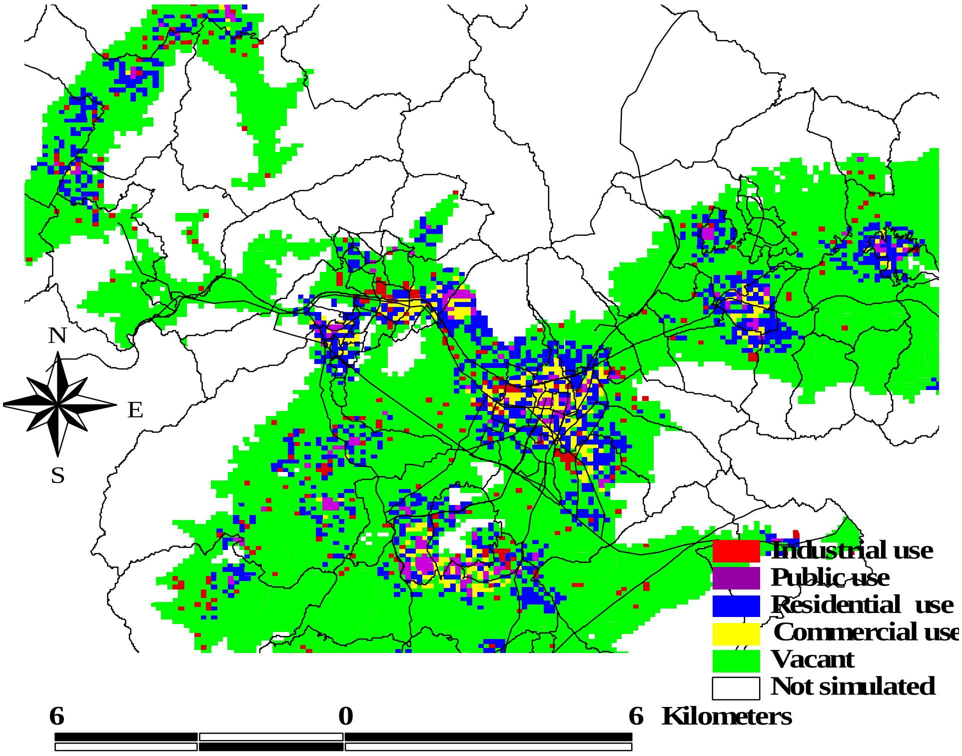


Figure 6 Land-use patterns simulated by probabilistic assignment

If probabilistic assignments are iteratively applied, the chance of getting unstable results increases. The simulation result totally depends on the set of random values; if different random numbers are given, very different results are expected in other trials. This dependency is stimulated when the assignment procedure is repeated. The succeeding developments will be attracted to the previously developed locations chosen by chance. Evolution of the indices of concentration as well as that of infrastructure needs in successive iterations under probabilistic assignment rule has been shown in figure 7,8 and 5 (right).

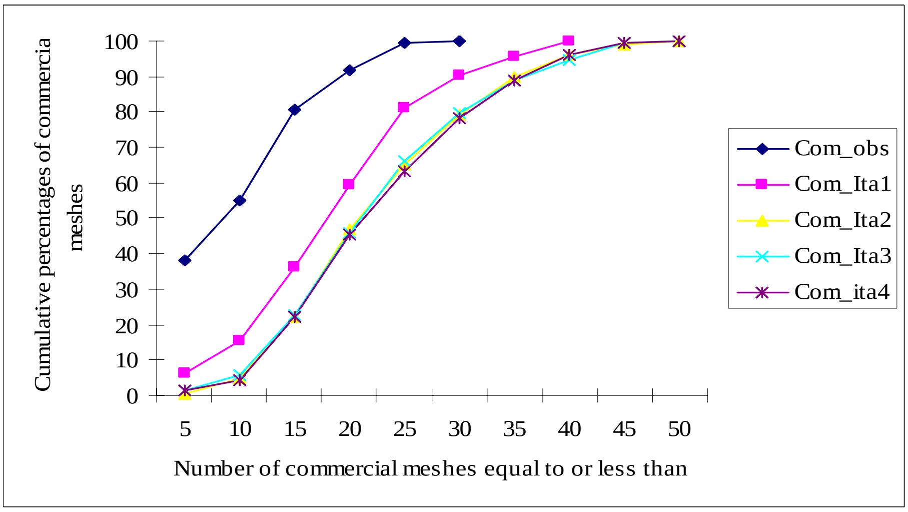


Figure7 Cumulative distribution of commercial use concentration index in probabilistic assignment

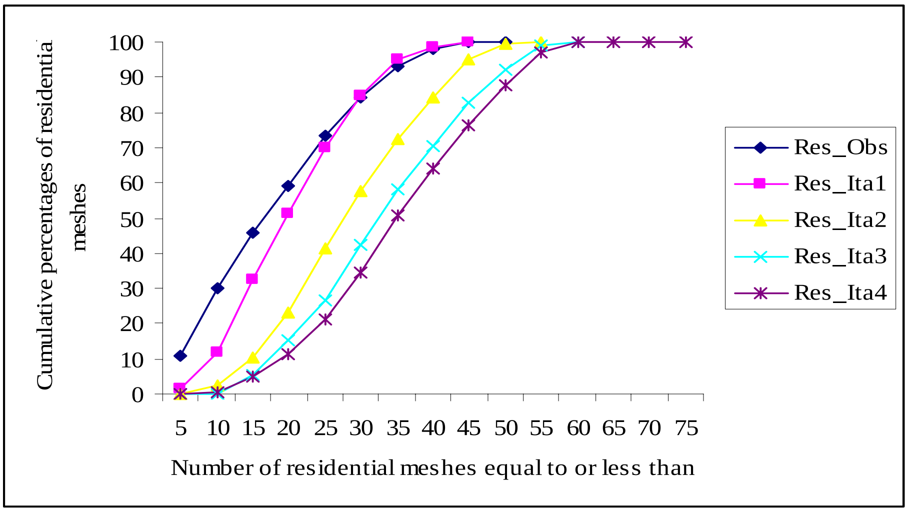


Figure 8 Cumulative distribution of residential use concentration index in probabilistic assignment

It was observed that, similar nature of downward displacement of cumulative distribution curve from observed distribution is noticed in Fig.7 and 8. Similar displacement of commercial concentration index curve at first iteration suggests commercial land-use distribution at fist iteration follows similar nature in both types of assignment procedures. However, saturation level of commercial concentration is observed one step after than that of deterministic assignment. Less displacement of residential concentration index distribution curve from observed distribution indicates that city's observed land-use pattern is not deterministically assigned but matches to some sort of randomness. Inertia that is put to any existing land use by land owner's self assessment of the situation stays on for many years before any significant change to take place. In case of infrastructure need index, as can be observed from figure 5 (right) that no systematic trend is observed suggesting instability of the results obtained from the probabilistic assignment procedure. Comparing iteration 1 situations, it can be observed that, in the probabilistic assignment case the infrastructure need index is higher than the deterministic assignment case, which suggests a more dispersed distribution of built-up areas in case of probabilistic assignment. But this dispersed pattern provides scope for the vacant land lots adjacent to built-up meshes to become built-up economizing the infrastructure need in subsequent iterations.

8. CONCLUSION

Computers are now widely used in developing operational simulation models needed for urban planning and urban management. Synthetic approach of building operational models to predict land use changes gained popularity with the increase availability of geographic data at finer resolution. Same approach of operational model building has been taken in this research using GIS, land-use data at reasonably fine resolution, and statistical model, to address some of the short comings of existing models. Besides, to facilitate requirements for strategic urban management, an index based approach of comparing prediction results was also proposed in this research. Findings of the research suggest the applicability of our approach in strategic urban management as this research provided a credible estimation of land-use concentration and future infrastructure needs. However, some limitations, such as coarse data resolution in time dimension, have also been revealed. To address such limitations finer resolution data in time dimension will be used in our future modeling effort. Besides, as only one time point data was used to predict future land-use pattern, the issue of inherent inertia that prohibits changes of land from one use to other could not be addressed. This will be done in future by taking account of the cost of change of land-uses from one use to other, which we believe, is the reason for the inertia that prohibits urban land use changes.

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