19-2 Pattern of Land-use Change in a Jakarta Suburb: Bekasi District

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1 Introduction

Knowledge of the rate of urbanization and its relationship with determining factors will contribute to more accurate land-use planning and related policy making. This study introduces a new approach to modeling the process of land-use change. A gravitational model is used to describe the distribution of urban land use in the area surrounding a city, and a statistical approach is employed for empirical testing of model parameters. The study focuses on: (1) finding the best model for analyzing the dynamics of urban land ratios and their growth rate with distance from the city; and (2) analyzing the spatial pattern of the distribution of urban land use in the suburban area of a city.

Land-use and other data for three years (1969/1970, 1981/1982, and 1993) for every desa* in Kabupaten Bekasi, West Java Province, Indonesia, were used. The scale of the 1969/1970 land-use maps was 1:50 000, and that of the 1981/1982 and 1993 maps was 1:25 000.

2 Modeling

a. Trends of land-use change in the suburbs

Urbanization growth rates in suburban areas (suburbanization) are affected by a push factor from the city core, by a pull factor from the attractiveness of the suburban areas[1,2,3], and also by accessibility to the city. The *urban land ratio* is proposed for describing the proportion of urban land use in a region; it is mathematically formulated as A_u/A or σ_u [4,5]. The *urban land ratio* of each *desa* in the study area is influenced by many factors. Accessibility to the city of Jakarta is a major factor in the suburbanization process. The derivation of the *urban land ratio* proposed in this study is formulated as follows:

$$\sigma_i = \frac{A_u}{A} = G_u \frac{M(t)^c T_i^d}{r_i^b} \qquad (1), \qquad PD_i = G_u \frac{M(t)^c T_i^d}{r_i^b} \qquad (2)$$

where σ_i is the *urban land ratio* of *desa** i in year t, G_u is a constant, $M(t)$ is the mass variable or push factor describing Jakarta's magnitude in year t, T_i is the attractiveness or pull force of *desa* i, r_i is the distance from *desa* i to the city of Jakarta, and c and b are the exponents of A_i and r_i, respectively, in year t. Note that if a similar distribution pattern of the population is assumed, it is possible to formulate a population-density (PD) model by equation (2).

The agglomeration factor is considered to be the attractiveness or pull factor of the *desa* and affects its *urban land ratio*. Some parameters describing the attractiveness/pull factor are proposed: population density of desa i (PD_i); population density of the urban area in desa i (MU_i); and accumulation of total population and urban area of region i and its surrounding region j, called *population agglomeration* (Pg_i) and *urban area agglomeration* (Ug_i), respectively, as described by equation (3).

**desa* is the smallest administrative unit in Indonesia, and corresponds to *shuraku* in Japan

$$Pg_i = \frac{P_i + \sum_{j=1}^{n} P_j}{A_i + \sum_{j=1}^{n} A_j}, \text{ and } Ug_i = \frac{A_{ui} + \sum_{j=1}^{n} A_{uj}}{A_i + \sum_{j=1}^{n} A_j} \quad (3)$$

where Pg_i and Ug_i are the population and urban agglomeration forces, respectively, of *desa i*, P_i and Au_i are the population and total of urban area of *desa i, respectively,* j is the *desa* adjacent to and surrounding *desa i*, P_j and A_j are population and total area of *desa j*, respectively, and Ai is the total area of *desa i*.

The third group of determinants, the accessibility factor, can be described using various measurements, such as the straight-line distance to the region in the suburbs measured from the center of the city of Jakarta (MONAS, National Monument, *Rs*, and from the exit point of Jakarta's main road at its border with Bekasi, *Rds*). Here the following road distance measurements were applied and tested statistically:

-$r_i = Rm_i$; $r_i = Rd_i$; $r_i = Rtot_i = Rm_i + Rd_i$; $r_i = \alpha Rm_i + \beta Rd_i$

b. The spatial pattern of suburbanization

The pattern of land-use change in the study area is described by the following parameters:

1. The *spatial mean* is obtained as an ordered pair that takes into account the position of the centroid of each region and the weight associated with the centroid. To describe the *spatial mean of the urbanized area* and the *spatial mean of population distribution* of a certain area, the following equations are proposed:

$$\overline{X_U} = \frac{\sum_{i=1}^{n} A_{ui} X_i}{\sum_{i=1}^{n} A_{ui}} \text{ and } \overline{Y_U} = \frac{\sum_{i=1}^{n} A_{ui} Y_i}{\sum_{i=1}^{n} A_{ui}} \quad (4); \qquad \overline{X_P} = \frac{\sum_{i=1}^{n} P_i X_i}{\sum_{i=1}^{n} P_{ui}}, \text{ and } \overline{Y_P} = \frac{\sum_{i=1}^{n} P_i Y_i}{\sum_{i=1}^{n} P_i} \quad (5)$$

where (X_i, Y_i) is geographical position of the center (centroid) of desa i, Aui is the total urbanized area of desa i, and $(\overline{X_U}, \overline{Y_U})$ and $(\overline{X_P}, \overline{Y_P})$ are the *spatial mean of the urbanized area* and *spatial mean of population distribution*. The movement of a spatial mean can indicate whether the suburbanization is undergoing an agglomeration or deglomeration process. Movement of a spatial mean towards the center indicates agglomeration, and movement outwards indicates deglomeration. The rate of agglomeration or deglomeration Vg is:

$$Vgu_{t1t2} = \frac{\sqrt{(\overline{Xu_{t2}} - \overline{Xu_{t1}})^2 + (\overline{Yu_{t2}} - \overline{Yu_{t1}})^2}}{t_2 - t_1} \quad (6); \qquad Vgp_{t1t2} = \frac{\sqrt{(\overline{Xp_{t2}} - \overline{Xp_{t1}})^2 + (\overline{Yp_{t2}} - \overline{Yp_{t1}})^2}}{t_2 - t_1} \quad (7)$$

where Vgu_{t1t2} and Vgp_{t1t2} are the speed of movement of the spatial mean of an urbanized area and population distribution, respectively, or the rate of agglomeration of an urbanized area and population.

2. The second parameter is the *dispersion index of the urbanized area*, formulated as:

$$S_{UX} = \frac{\sum_{i=1}^{n} A_{ui} X_i^2}{\sum_{i=1}^{n} A_{ui}}, \; S_{UY} = \frac{\sum_{i=1}^{n} [A_{ui}(Y_i - \overline{Y})^2]}{\sum_{i=1}^{n} A_{ui}} \quad (8); \qquad S_{PX} = \frac{\sum_{i=1}^{n} P_i X_i^2}{\sum_{i=1}^{n} P_i}, \; S_{PY} = \frac{\sum_{i=1}^{n} [P_i(Y_i - \overline{Y})^2]}{\sum_{i=1}^{n} P_i} \quad (9)$$

where Su_X is the dispersion of the urban area distribution index in the X-axis direction, and Su_Y in Y-axis direction. The higher the Sp_X and Sp_Y, the more dispersed the suburbanization; lower values indicate that the agglomeration process is stronger than that of deglomeration.

3. The third spatial pattern parameter is the distance r of the 25th percentile (first quartile) ordered set of urban areas, $r(QiU)$ and populations, $r(QiP)$. The absolute value of Qi has little meaning, but its change over time is

meaningful: an increase of *Qi* over time indicates deglomeration and *vise versa*. In the case of suburbanization in three years, *t1*, *t2* and *t3*, agglomeration is indicated when:

$$r(QiU)_{t1} > r(QiU)_{t2} > r(QiU)_{t3}, \text{ and deglomeration when } r(QiU)_{t1} < r(QiU)_{t2} < r(QiU)_{t3}.$$

3 Results

Rd is the best predictor for describing the significance to the *urban land ratio* of distance. In 1969/1970, the *urban land ratios* of all *desas* in the study area were relatively similar compared with those in 1981/82 and 1993. *Desas* located closest to the main road (regions with the smallest *Rs*) tended to have become more urbanized and changed faster than those further away. Note that the relationship between *urban land ratio* and distance is nonlinear.

Table 1 Coefficients of regression and t-ratios of the *urban land ratio* model, 1969

Predictors	1st equation	2nd equation	3rd equation	4th equation
1. Constant	5.06 (14.92)***	4.62 (12.91)***	4.76 (13.28)***	5.03 (16.42)***
2. *ln Rds*				-0.071 (-2.88)***
3. *ln Rs*	-0.091 (-2.15)**			
4. *ln Rm*		NS		
5. *ln Rd*		NS		
6. *ln Rtot*			NS	
7. *ln PD*	0.993 (31.15)***	0.995 (29.40)***	0.990 (30.17)***	0.995 (31.94)***
8. *ln Pgl*	NS	NS	NS	NS
9. *ln Ugl*	NS	NS	NS	NS
10. *ln MU-r*	-0.970 (-41.51)***	-0.972 (-39.82)***	-0.972 (-40.21)***	-0.968 (-42.30)***
R^2	98.7%	98.6%	98.6%	98.7%
R^2(adj)	98.6%	98.5%	98.5%	98.7%

According to equation (2) the *urban land ratio* model is a multivariate rather than a bivariate function. Distance is not a single predictor of urban land ratio function, there are some more variables that could be assumed as predictors. Therefore, the urban land ratio function should be a multivariate model. By employing the least squares method, several multivariate regression functions were tested as possible models. To make the regressions linear, all variables were transformed to linear-logistic (*ln*) variables. Based on statistical tests, the best subsets of these models for each year are as shown in Tables 1, 2 and 3, respectively.

Table 2 Regression coefficients and t-ratios of the *urban land ratio* model, 1981

Predictors	1st equation	2nd equation	3rd equation	4th equation	5th equation	6th equation	7th equation	8th equation
1. Constant	-4.40 (-3.27)***	-7.43 (-5.73)***	-5.73 (-4.34)***	-6.19 (-5.07)***	3.64 (2.76)***	4.21 (3.16)***	3.81 (2.93)***	2.83 (2.24)**
2. *ln Rds*				NS				-0.23 (-2.34)**
3. *ln Rs*	-0.329 (-1.82)*				-0.52 (-3.01)***			
4. *ln Rm*		NS				-0.099 (-2.05)**		
5. *ln Rd*		0.11 (1.74)*				-0.19 (-3.16)***		
6. *ln Rtot*			NS				-0.32 (-3.28)***	
7. *ln PD*	0.85 (9.95)***	0.92 (10.5)***	0.87 (10.0)***	0.88 (10.3)***				
8. *ln Pgl*	-0.27 (-2.35)**	NS	-0.25 (-1.97)*	-0.22 (-1.79)*	0.43 (3.95)***	0.304 (2.50)**	0.35 (3.00)***	0.42 (3.69)***
9. ln *Ugl*	0.35 (3.90)***	0.32 (3.42)***	0.35 (3.85)***	0.35 (3.78)***	NS	NS	NS	NS
10. *ln MU-r*					-0.86 (-10.7)***	-0.93 (-11.6)***	-0.89 (-11.2)***	-0.89 (-11.1)***
R^2	59.3%	59.4	58.5	58.4%	61.9%	62.8%	62.3%	60.9%
R^2(adj)	58.2	58.0	57.3	57.2%	60.8%	61.5%	61.2%	59.9%

Table 3 Regression coefficients and t-ratios of the *urban land ratio* model, 1993

Predictors	1^{st} equation	2^{nd} equation	3^{rd} equation	4^{th} equation
1.Constant	NS	NS	NS	NS
2. ln Rds				NS
3. Ln Rs	NS			
4. Ln Rm		NS		
5. ln Rd		-0.012 (-2.62)***		
6. ln Rtot			NS	
7. ln PD	1.000 (147.6)***	0.994 (143.39)***	0.996 (140.83)***	0.998 (147.02)***
8. ln Pgl	NS	NS	NS	NS
9. ln Ugl	NS	NS	NS	NS
10. ln MU-r	-1.000 (-186.32)***	-0.997 (-188.98)***	-1.000 (-192.68)***	-1.000 (-191.41)***
R^2	99.7%	99.7%	99.7%	99.7%
R^2(adj)	99.7%	99.7%	99.7%	99.7%

1. *ln*: linear logistics; *Rds*: straight-line distance from Jakarta-Bekasi border on the outlet road from Jakarta City to region *i*, km; *Rs*: straight-line distance from Jakarta City center (*MONAS*) to region *i*, km; *Rm*: main road distance to the region *i* (km); *Rd*: road distance from the main road to the region *i*; *Rtot = Rm + Rd* (total main road), km; *PD:* population density (people/km2); Pg_i: population agglomeration index; Ug_i: urban area agglomeration index; *MU*: population density of urban area
2. *** : 99.5% confidence; **: 95% confidence; *: 90% confidence; and NS: not significant (<90% confidence)
3. N = 232

During 1969 to 1993, many *desas* grew more urbanized, especially those closer (i.e. having better access) to Jakarta City. In order to analyze the *urban land ratio* model, Least Squares Method is employed, and several alternatives of distance *r*, and attractiveness factors T_i for the year 1969 are used. The best-fit equations in 1969/70 (Table 1) reached 98.7% of the total sum of squares (variability). The results show that road distance was not a good proxy of distance in 1969/70, although the straight-line distances *Rs* and *Rds* were significantly related to suburbanization. In 1981/82 (Table 2), all distance measurements were found to influence suburbanization significantly, but in 1993 (Table 3), only *Rd* (distance from the main road) significantly influenced suburbanization.

Table 4 Regression coefficients and t-ratio of the best three subset of population density (*PD*) function

Predictors		coefficient and t-ratio					
		1^{st} equation	2^{nd} equation	3^{rd} equation	4^{th} equation	5^{th} equation	6^{th} equation
1	Constant	-2.00 (-1.72)*	0.62 (1.78)*	1.01 (3.94)***	NS	1.05 (4.26)***	NS
2	ln Rds						
3	ln Rs						
4	ln Rm	0.021 (1.68)*	0.0208 (1.67)*	0.021 (1.67)*	0.021 (1.69)*	0.021 (1.67)*	0.021 (1.67)*
5	ln Rd	-0.131 (8.80)***	-0.131 (-8.81)***	-0.131 (-8.81)***	-0.131 (-8.78)***	-0.131 (-8.80)***	-0.131 (-8.81)***
6	ln Rtot						
7	ln Pg	0.765 (27.34)***	0.765 (27.29)***	0.765 (27.30)***	0.766 (27.34)***	0.765 (27.27)***	0.765 (27.27)***
8	ln JP	0.25 (27.34)***					
9	ln JG		0.073 (3.08)***				
10	ln JGP			0.10236 (3.08)***			
11	ln JPD				0.29151 (2.99)***		
12	ln JGA					0.07635 (3.0)***	
13	ln JGA						0.05849 (3.07)
R2		60.4%	60.4%	60.4%	60.4%	60.4%	60.4%
R2 (adj)		60.3%	60.3%	60.3%	60.3%	60.3%	60.3%

1. *ln*: linear logistics; *Rds*: straight-line distance from Jakarta-Bekasi Border on outlet road of Jakarta city to the region *i*, km; *Rs*: straight-line distance from Jakarta City center (*MONAS*) to the region *i*, km; *Rm*: main road distance to the region *i* (km); *Rd*: road distance from the main road to the region *i*; *Rtot = Rm + Rd* (total main roads, km; Pg_i: population agglomeration index; Ug_i: urban area agglomeration index; *MU*: population density of urban area; *JP*: population of Jakarta city; *JG*: GDP of Jakarta; *JGP*: GDP per capita of Jakarta; *JGA*: GDP/km2 of Jakarta.
2. *** : 99.5% confidence; **: 95% confidence; *: 90% confidence; and NS: not significant (<90% confidence).
3. N = 1449

The statistical tests also showed that the population density PD_i of *desa i* and the urban area population density MU_i were the best proxies for describing the attractiveness of a region for suburbanization. Table 4 shows the best subsets of parameters for describing the function *PD* (population density) in the suburbs; they include several alternative push factors (the mass of Jakarta City) as explanatory variables. *Rd*, distance from the main road, was found to have a significant impact, indicating the importance of the main road facility on population distribution in the suburban area. There has been population agglomeration and increasing population in the suburbs, indicating that most of the suburban areas are still relatively unsaturated. The more populated areas tend to be more attractive rather than having the effect of pushing people to move out. The large population and economic growth of Jakarta City have resulted in significant increases in the populations of the City's suburbs.

Table 5 shows some parameters for describing the land-use pattern in the study area. In the first period, the position of the *spatial mean of the urbanized area* moved in a southwesterly direction becoming closer to the city, and then moved in a southeasterly direction in the second period. However, the position of the *spatial mean of population distribution* moved consistently in a southwesterly direction. The *dispersion index of urbanization* in the east-west direction, Sx, became smaller in the first period and increased in the second period, while Sy showed the opposite trend. The *dispersion index of population distribution* on Sx and Sy decreased in both periods.

The results show that the suburbanization process in terms of the expansion of urban land use showed a different pattern to that in terms of population expansion. In the first period, the overall pattern exhibited an agglomeration or concentration of urban activity towards Jakarta City rather than a dispersion or deglomeration process. In the second period, expansion of urban land-use became more dispersed rather than agglomerating, but the concentration of the population had not changed. The population distribution was an agglomeration process during both periods.

Table 5. Spatial urban and population distribution parameters for 1969/70, 1981/82 and 1993

	Parameters	1969/1970 (t_1)	1981/1982 (t_2)	1993 (t_3)	Growth (t_1 - t_2)	Growth (t_2 - t_3)
1	spatial mean of					
	a. Urban area $(\overline{X_u}, \overline{Y_u})$	(28.5, -7.2)	(27.0, -8.6)	(29.1, -8.5)	0.17	0.19
	b. Population distribution $(\overline{X_P}, \overline{Y_P})$	(30.1, -7.3)	(28.4, -7.4)	(25.6, -7.9)	0.14	0.26
2	Dispersion index of					
	a. urbanized area *Sux*, *Suy*	933.5, 41.2	845.2, 163.8	949.0, 150.0		
	b. population *Spx*, *Spy*	1013.8, 155.1	918.7, 140.7	759.9, 129.7		
3	Spatial border of the closest 25% area of:					
	a. urban land *Rds (QiU)*, *Rm (QiU)*, *Rd (QiU)*	11.1, 6.1,2.3	11.4, 6.1, 3.6	9.8, 6.8, 1.6		
	b. population *Rds (Q1P)*, *Rm (Q1P)*, *Rd (Q1P)*	12.0, 8.0, 2.3	10.0, 6.1, 1.7	7.8, 4.2, 1.6		

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