Assessing Residential Clustering for Park Area Development

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ABSTRACT

Greenbelt Zones or park areas such as cave areas have strong zoning restrictions that prevent developments. However, whenever it is needed to free the restrictions for development, planning departments are faced with the problems of which part in the area should select. Especially when households are scattered in small groups, there must be a clear guidelines in order to determine the areas having high potential for development while minimizing resistance from the residents. The methodologies should include means to incorporate many different aspects of decision elements. This study presents strategies to choose groups of residents by employing the concentration index of them and means to incorporate preferences among different decision factors using the AHP method.

Keywords: Greenbelt, GIS, AHP, overlay, cluster

1. INTRODUCTION

It becomes often the debatable when it comes to selecting the households to be freed from zoning restrictions for development. Such cases are observed especially in those areas where development restrictions are strongly enforced. Restricted Development Zones (or Greenbelt Zones) or park areas such as cave areas have strong zoning restrictions that are intended to prevent urban sprawl and protect natural environment. However, due to resistance from the residents in such areas, actions to make the rules less strict have been taken from time to time. However, selecting portions in protected areas and drawing boundaries on them which have no visual marks will justifiably bring about a great deal of resistance and conflicts. The initial step should be devising strategies that can minimize such problems before implementing regulation measures. The methodologies should include means to incorporate many different aspects of decision elements and stakeholders' interests while being as subjective as possible.

This study presents strategies to choose groups of residents in protected areas by employing the concentration index of them and means to incorporate preferences among different decision factors using the AHP method.

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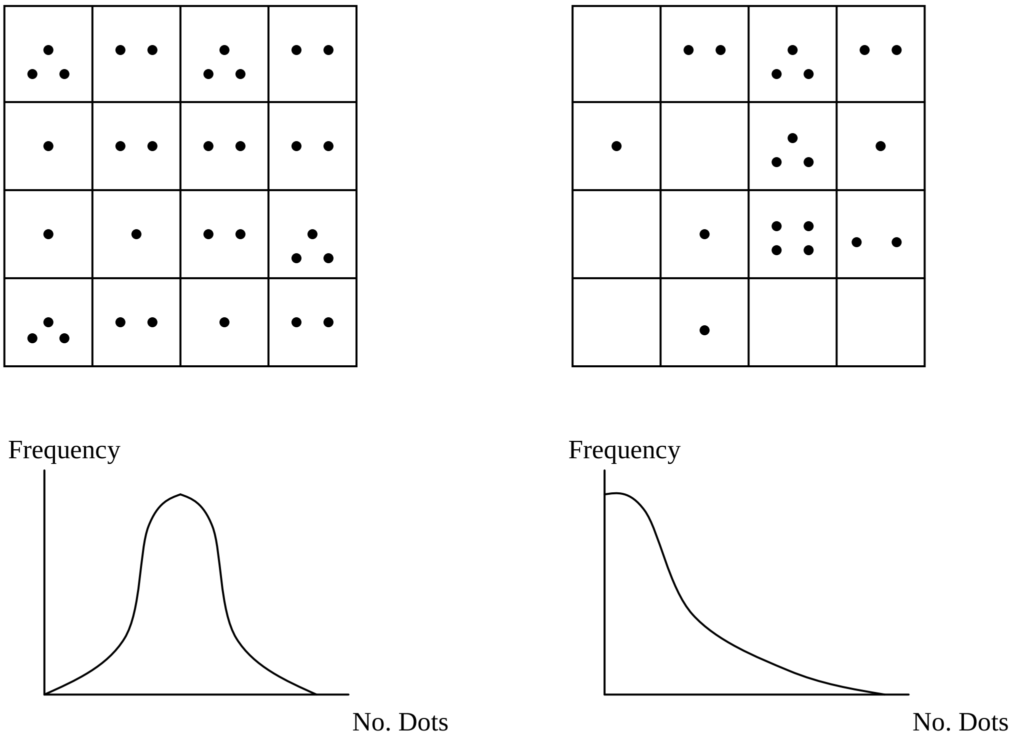
2. ANALYSING SPATIAL CLUSTERING

It is viewed that partial relaxation will primarily be based on how many and how densely existing households are placed in the protected zones. The process will need to involve the steps for differentiating those residential areas from other part. This section presents reviews on existing approaches relating to analyses for dot-distribution patterns and presents a relevant strategy that can now be practically applicable to adjustment processes.

2.1 Quadrat Analysis

Quadrat analysis is represented by the probability density function that describes the number of objects placed in a grid of a space (Lee 1989, Thomas 1977). The given space is first divided into grids of same shape and size and the number of dots that belong to each grid are counted. As shown in Figure 1, the Quadrat Analysis classifies type (a) as random pattern and type (b) as clustered pattern using the ratio of variance to the mean. If the pattern is completely regular where each grid holds the same number of dots, the ratio becomes 0. The ratio becomes larger as the dots become concentrated on smaller number of grids with variance increasing.



(a) random pattern

(b) clustered pattern

Figure 1. The Quadrat Analysis

The drawback, however, is that the same dot distribution pattern can be classified into either random pattern or clustered pattern depending on the size of the unit grid. Also, although this method helps to understand the degree of concentration of dot-distribution in the study area, it does not provide means to select those clustered portions.

2.2 Nearest-Neighbor Analysis

Nearest-Neighbor Analysis describes the distribution pattern using the distance of the nearest two points (Lee 1989, Getis 1964). It compares the actual mean distance ($\bar{d}_a$) from each point to its nearest point and the random mean distance ($\bar{d}_e$) which is that of randomly distributed points and evaluates how much the observed distribution of dots is deviated from theoretical distribution.

$$\bar{d}_a = \frac{\sum_i \min d_i}{n}, \tag{1}$$

where d_i is the distance of two points and n is the number of dots.

$$\bar{d}_e = \frac{1}{2}\sqrt{\lambda}, \tag{2}$$

where $\lambda = \frac{n}{A}$, n is the number of dots and A is the size of the space.

The Nearest-Neighbor Index R is described by the ratio of these two.

$$R = \frac{\bar{d}_a}{\bar{d}_e} \tag{3}$$

R has a value from 0 to 1, being 1 in case of completely random distribution and 0 when the dots are concentrated on one point.

Nearest-Neighbor Analysis has merit over Quadrat Analysis in that it is not affected by the size of unit grid, but its major drawback is that the result varies depending on the size of study area. Similarly to Quadrat Analysis, it is a method to measure the concentration degree of dots among the given space and cannot be applied to differentiating the concentrated area from other parts.

2.3 Overlap Analysis

Contrast to the previous approaches which use either the number or distance of dots to calculate the degree of concentration in the study area, Overlap Analysis uses overlapped areas created by unit circles centering around randomly distributed dots and the mean distance of them (Koh 1995). Overlap Analysis analyzes the distribution of dots by calculating the ratio of total overlapped area to the total area of unit circles as follows.

$$V = N\pi r_i^{\,2}, \tag{4}$$

where N is the number of dots and r_i is the mean half distance of two points.

$$C = \frac{P}{V} = \frac{\sum A_i n_i}{N\pi r_i^{\,2}}, \tag{5}$$

where C is the overlap index, P the sum of overlapped areas, V the summed area of unit circles, and the overlapped area A_i belongs to n_i number of circles. The overlap index C becomes 1 when entire points are placed in one spot while 0 in case of the random distribution.

2.4 Using Buffering on the Overlap Analysis

The methods discussed so far all deal with how many the entire dots in a given space are clustered and not how they are visually circumscribed or demarcated, which is the major concern in actual lifting processes in protected zones. For such purpose, we can use the buffering function that most GIS packages provide. As shown in Figure 2, we can easily draw polygons around existing buildings by using the buffering function with user-specified set-off distance. Polygon areas vary depending on the input radius resulting in different grouping such as A, B, C and D in the figure. For example, we can group B, C and D into one using longer buffer-radius or exclude some small groups according to decision strategies.

Apart from grouping of buildings, the steps are required to analyze how densely buildings are placed in each group. By doing so, we can compare similarly grouped villages based on their concentration densities and, thus, can provide more validity in selecting the villages to be freed or alleviated from restrictions.

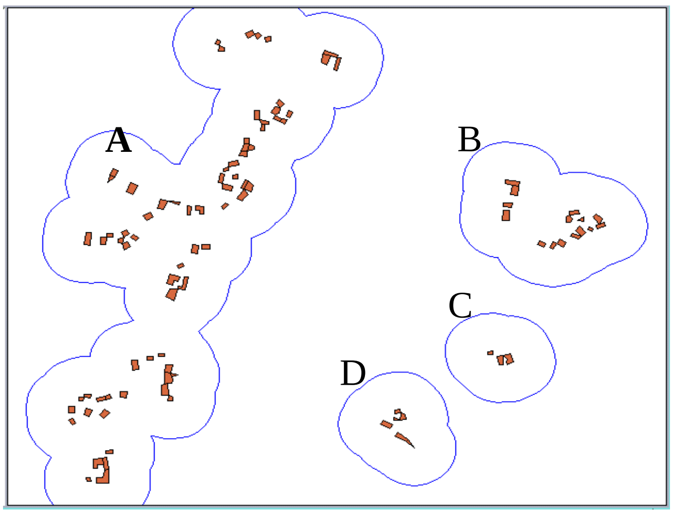
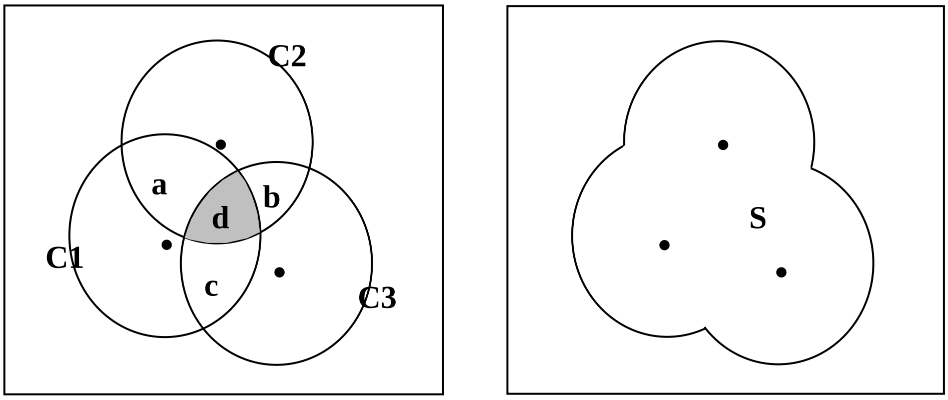


Figure 2. An example of grouping houses using the buffering function of the GIS



(a) overlaps of buffered circles (b) circumscription of overlapped buffers

Figure 3. Buffering of dots and the concentration index

The idea that was discussed in Overlap Analysis method, which is based on the overlapped areas of unit circles, can be modified and applied to establishing clusters of houses using the GIS-buffering. Figure 3 shows (a) the overlapping of buffered circles and (b) the cluster polygon that circumscribes them. If we follow the formula (4) and (5), the ratio of the total overlapped areas (2(S(a)+S(b)+S(c))+3S(d)) to the sum of the buffered circles (S(C1)+S(C2)+S(C3)) becomes as follows.

$$C = \frac{2(S(a)+S(b)+S(c))+3S(d)}{S(C1)+S(C2)+S(C3)}$$

However, this formula has a defect in that it generates same value 1 when the participating dots are placed in one spot regardless of the number of them. Since we should regard a resulting polygon (ie. S in Figure 3) from the buffer operation as being more densely populated as it contains more dots in it, we should modify the current denominator which is the aggregation of circles to the entire polygon. Also, the numerator needs to change to the aggregation of each overlapped area multiplied by the number of overlaps taken place regarding to it as follows.

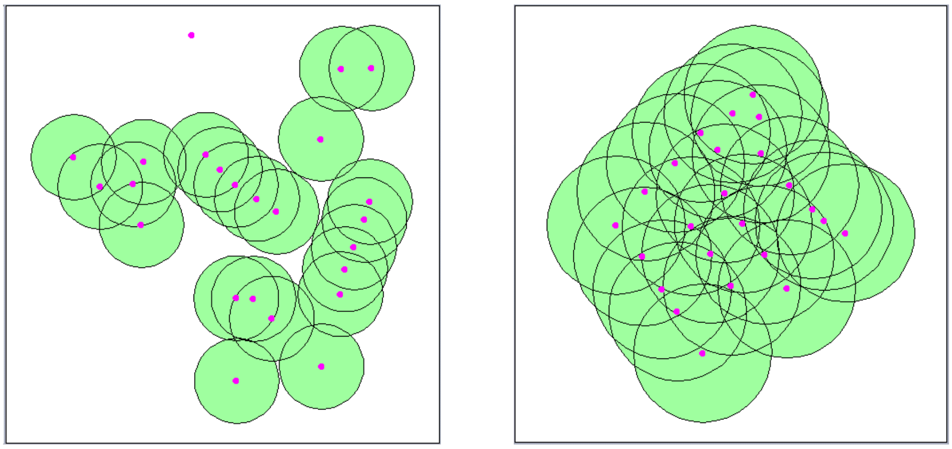
$$C = \frac{S(a)+S(b)+S(c)+2S(d)}{S}$$

By calculating the ratio of the sum of overlapped areas (taking into account the number of overlaps for each overlapped area) to the entire polygon resulting from dot-buffers, we can understand how densely houses are gathered in their clusters. This idea can be generalized as follows.

$$C = \frac{\sum A_i n_i}{S} \quad , \tag{6}$$

where the overlapped area A_i multiplied by n_i–times of overlaps and S is the union area of buffered circles.

The concentration index C generated from this formula becomes 0 in case of having no overlapped areas and N-1 when N buffered circles are fully overlapped, that is, all N dots are placed in one spot.If we assign concentration indexes to the buffered polygons as one of their attributes, we can compare the residential clusters based on these values. For example, polygon S in Figure 3 may have 0.5 as its attribute. Two residential clusters with the same number of households are compared in Figure 4 based on their concentration indexes.



(a) C = 0.723 (b) C = 3.014

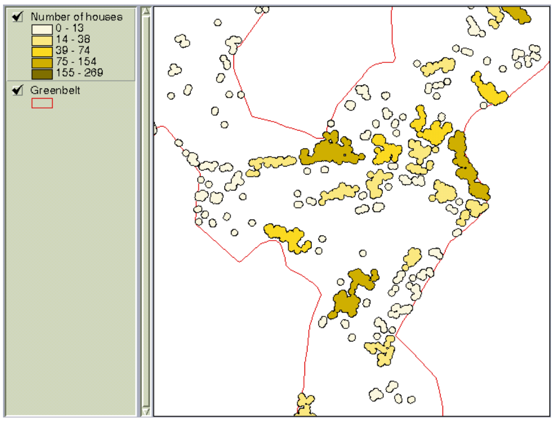
Figure 4. Concentration degrees of two clusters with the same 23 houses

This methodology was applied to a portion of an actual RDZ to generate buffered zones and their concentration indexes as illustrated in Figure 5.

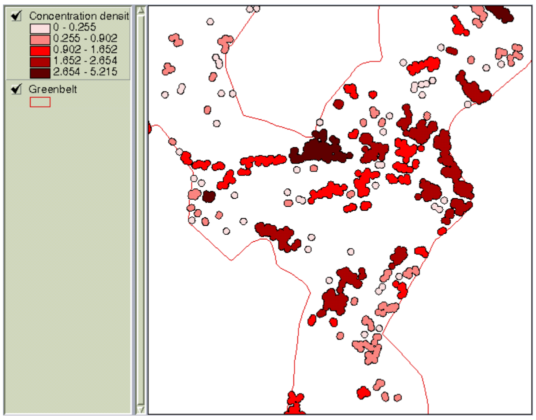
3. COMPOSITE ANALYSIS

3.1 Generating development-priorities using the overlay

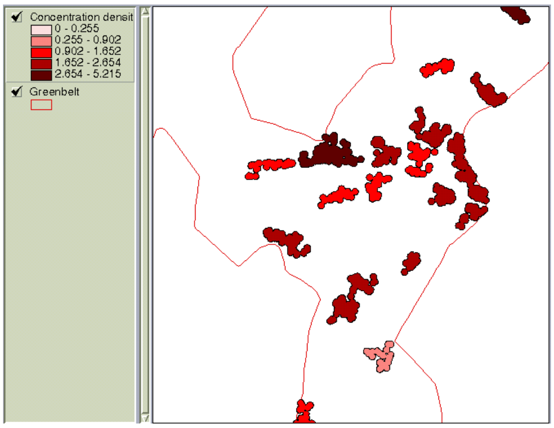
In order to analyze the ‘developability’ or the priority for restriction-lifting among the clusters of houses, different decision factors should be taken into account. Not only should the decision making include various factors such as slope, elevation, distance to CBD, distance to highway/railroad, land price and environmental protection, but it should take into account that each of them has different importance or weight value. If we assume that more physical and environmental elements a site satisfies, more developable it becomes, the overlay function of GIS can be effectively applied to such problems.



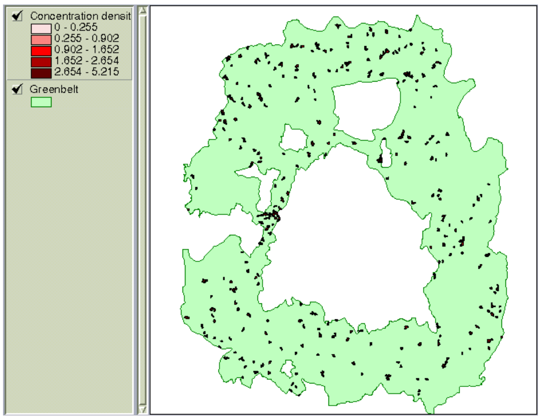
(a) The number of households in buffered areas



(b) The concentration degrees of buffers



(c) The buffers having 20 or more households



(d) 20 or more household-areas in an entire RDZ

Figure 5. Creating buffers and displaying them based on the concentration index

The development priorities can be obtained by using overlay function to find areas that satisfy decision criteria and then to overlay these areas with residential clusters that are created from buffer analysis. If each of decision criteria is categorized and assigned scores accordingly, the resulting overlaid map contains the aggregated scores, which represent the weight value for development or restriction-easing. Table 1 illustrates how decision elements are classified and assigned scores. This example assigned scores to different classes in proportion to their areas.

Table 1. An example of assigning class scores based on class areas

score	concentration index	Distance to CBD (meters)	slope (meters)	elevation (meters)	land price (won)
1	0 - 0.089	14500 - 18700	18 - 64	212 - 570	59209 - 82029
2	0.089 - 1.456	12700 - 14300	12 - 17	153 - 211	85114 - 127377
3	1.456 - 2.061	10700 - 12500	7 - 11	115 - 152	129371 - 197415
4	2.061 - 2.694	8700 – 10500	3 - 6	81 - 114	205283 - 229990
5	2.694 - 5.215	3100 – 8500	0 - 2	35 - 80	267902 - 534401

3.2 Dealing with the weight values of decision criteria

It is practical to assign different weight values to decision criteria since they have different importance each other. A technique in MCDM field called the AHP(Analytical Hierarchy Process) can be effectively used in comparing and prioritizing multiple criteria. The AHP which was developed by Saaty (1980) is a decision analysis technique used to evaluate complex multi-attributed alternatives. The AHP employs a systematic procedure for representing the elements of a problem hierarchically, enabling the subproblems to be easily evaluated. Simple pairwise comparisons are used for developing priorities in each hierarchy. Theoretical background of the AHP can be found in voluminous literature (e.g. Yager 1979, Saaty and Kearns 1985, Saaty 1980, 1987, 1990), and, hence, will not be discussed here. Table 2 illustrates how prioritized values are assigned based on the pairwise method and input to matrix for the calculation of entire weight values. Figure 6 shows a computer output containing the final weight values.

Table 2. Prioritizing process using the pairwise comparison

	con. index	CDB dist	Slope	elev.	lprice
con. index	1	**4**	**5**	**8**	**2**
CDB dist	1/4	1	**2**	**4**	**1/2**
slope	1/5	1/2	1	**2**	**1/3**
elev	1/8	1/4	1/2	1	**1/4**
lprice	1/2	2	3	4	1

	OVERLA	DISTAN	SLOPE	ELEVAT	LPRICE	WEIGHT
OVERLA	1.0000	4.0000	5.0000	8.0000	2.0000	0.4620
DISTAN	0.2500	1.0000	2.0000	4.0000	0.5000	0.1571
SLOPE	0.2000	0.5000	1.0000	2.0000	0.3333	0.0884
ELEVAT	0.1250	0.2500	0.5000	1.0000	0.2500	0.0506
LPRICE	0.5000	2.0000	3.0000	4.0000	1.0000	0.2418

Figure 6. Calculation of weight values using the AHP

Physical criteria can now be multiplied by weight values before they participate in overlay process and then the resulting map contains aggregated scores where different importance is reflected. Figure 7 displays the residential clusters having 20 or more houses according to aggregated weight values.

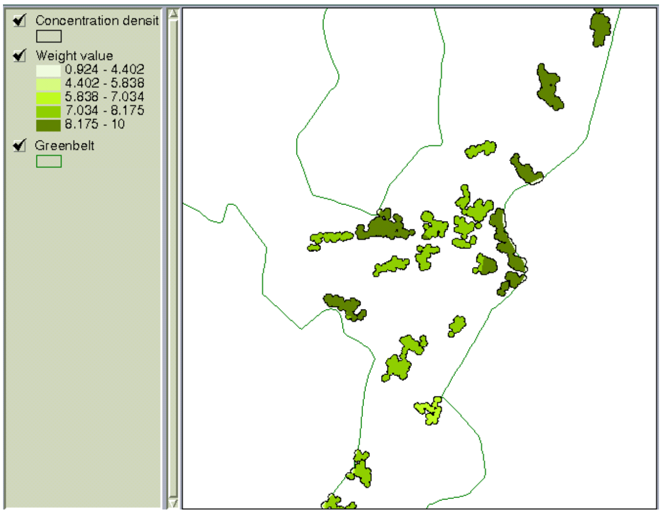
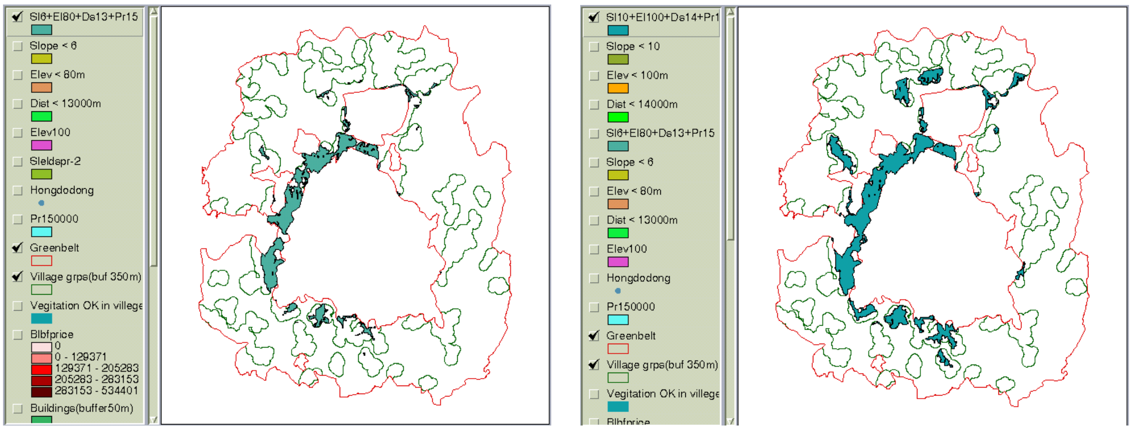


Figure 7. Aggregated weight values of clusters having 20 or more houses

Weight values can also be regarded as 'looseness' for condition variation in each decision criteria. Decision criteria with higher weight values can be viewed to play more critical role than others among the criteria included in overlay operation, which means condition modification of that criteria becomes more difficult or 'dangerous' than others. For example, Figure 8-(a) illustrates the areas having conditions of slope 6% or more, elevation below 80 meters, distance less than 1.3 km to CBD, and over 150000 won as the land price per pyung (1 pyung approximately equals to 3.3 m^2). If the total area is not large enough and, thus, conditions need to be adjusted, weight values can be applied in loosening the conditions. Figure 8-(b) now displays loosened conditions with slope less than 10%, elevation less than 100 meters, distance less than 1.4 km to CBD and over 150000 won as the land price per pyung.



(a) Before loosening constrainst

(b) After loosening constraints

Figure 8. Using the weight values for loosening the constraints

We must note that the AHP does not provide mathematically rigorous results and is a technique that helps systemize objective evaluations. Although the AHP does not yield exact numbers for the priorities of decision criteria, it can effectively help accommodate and adjust ideas from multiple decision makers.

4. CONCLUSIONS

Lifting restrictions in protected areas is one of the most difficult problems that governments must tackle with. We can easily foresee complaints from the residents during the processes of choosing the areas to be freed from restrictions. One way to minimize them will be to establish strategies that are consistent and reasonable, which, however, will never be easy. With these issues in mind, this study presented that concentration index can be adopted as a tool to evaluate or choose residential clusters. Along with this, using the AHP technique was introduced in prioritizing multiple decision factors comprehensively.

Of course, such techniques also require steps to set up some forms of principles. For example, providing different buffer distances yields different forms and numbers of residential clusters and setting different scoring schemes generates different scores in the final integration. Also, such steps would be required to determine how many classes are needed in the attribute values or where to divide the classes.

These are some of the problems to be handled in the future study and yet it is viewed that the proposed techniques including the concentration index and the AHP in the GIS environment help decision makers in creating and comparing different alternatives. By refining and improving the techniques, planners will be aided in narrowing down wide discrepancies among stakeholders.

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