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Priority Modeling for Public Urban Park Development in Feasible Locations Using GIS, Intuitionistic Fuzzy AHP, and Fuzzy TOPSIS

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***Abstract*—As feasible locations of public urban park in Bogor Municipality have been acquired in a previous study, decision makers are urgently needed to be informed on which locations should be prioritized for public urban park (PUP) development. Therefore, this study aggregates four multi-spatial criteria for PUP development priority modeling, namely distance to slum neighborhood, accessibility, slope, and land value. These four criteria in form of vector datasets were weighted using intuitionistic fuzzy analytical hierarchy process (IF-AHP) to consider the hesitancy, vagueness, and fuzziness might arise from experts' judgement as well as from multi-spatial data processing. Resulted criteria weights from IF-AHP show that accessibility weight 0.261, land value weight 0.259, distance to slum weight 0.255, and slope weight 0.225, respectively. Criteria weights were inputted into fuzzy technique for order preference by similarity to the ideal solution (TOPSIS) and geographic information system (GIS) to rank location priority. Results from fuzzy TOPSIS show that very high priority class which has the biggest CCi values range (>0.654-0.76) provides 0.14 km2 area of feasible PUP development scattered in 10 locations. The biggest area for feasible PUP development is generated by medium priority class (CCi values >0.439-0.546) in 26 locations and approximately area of 0.38 km^2.**

Keywords: ***priority modeling, public urban park, GIS, IF-AHP, fuzzy TOPSIS***

***Abstrak*—Dengan telah tersedianya lokasi-lokasi potensial taman kota publik di Kota Bogor dari studi sebelumnya, maka pengambil keputusan perlu diinformasikan lokasi mana saja yang harus diprioritaskan untuk pembangunannya. Oleh karena itu, penelitian ini menggabungkan empat kriteria multi spasial untuk prioritas pembangunan taman kota publik, yaitu jarak ke permukiman kumuh, aksesibilitas, kemiringan lahan, dan nilai tanah. Kriteria-kriteria tersebut dalam bentuk data vektor dibobotkan menggunakan metode intuitionistic fuzzy analytical hierarchy process (IF-AHP) untuk mempertimbangkan keraguan, ketidaktepatan, dan ketidakpastian yang mungkin timbul dari pertimbangan para ahli dan pengolahan data multi spasial. Bobot kriteria yang dihasilkan dari IF-AHP menunjukkan nilai bobot aksesibilitas 0,261, bobot nilai tanah 0,259, bobot jarak ke permukiman kumuh sebesar 0,255, dan bobot kemiringan lahan 0,225. Bobot dari masing-masing kriteria kemudian digunakan dalam proses peringkat lokasi prioritas pembangunan taman kota menggunakan metode fuzzy technique for order preference by similarity to the ideal solution (TOPSIS) dan sistem informasi geografis (SIG). Hasil pengolahan dari fuzzy TOPSIS menunjukkan bahwa kelas prioritas sangat tinggi untuk pembangunan taman kota publik dengan nilai CCi (>0,654-0,76) memiliki luas sekitar 0,14 km2 tersebar di 10 lokasi. Sedangkan wilayah terluas diperoleh dari kelas prioritas menengah dengan nilai CCi antara >0,439 sampai 0,546 dengan 26 lokasi dan luas sekitar 0,38 km^2.**

Kata kunci: ***pemodelan prioritas, taman kota publik, sistem informasi geografis, IF-AHP, fuzzy TOPSIS***

I. Introduction

A Recent study on searching feasible public urreban park (PUP) locations in Bogor Municipality, Indonesia has been performed, considering spatial criteria, fuzzy logic, and feasible land use land cover [1], it shows that feasible PUP locations generated from Suitability Level 7 (SL-7) is the best because it compatibles with PUP area demand in most villages of Bogor Municipality. SL-7 feasible locations were resulted from combined methods of fuzzy aggregation and fuzzy inference systems (FISs) namely, Fuzzy DEMATELs [2], Mamdani, Sugeno-1, and Sugeno-0.

Given with scattered feasible PUP locations resulted from SL-7 analysis, decision makers of PUP management in Bogor Municipality need to be informed on how to prioritize feasible PUP locations for development. In a previous study, priority of urban park development was

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achieved using combined technique for order preference by similarity to the ideal solution (TOPSIS), analytical hierarchy process (AHP) and geographic information systems (GIS) [3].

In Bogor Municipality, choosing the primary locations of feasible PUP depends on the available budget, therefore land value inevitably is the main criteria. In addition, PUP construction cannot be implemented without adequate access to the locations. A PUP also serves as a social interaction place for the visitor, and this is not happening in slum neighborhood when crowded houses occupy spaces. Hence, development goal in Bogor Municipality is to construct PUP near the slum area. PUP projects depend on the slope, where locations with extreme slope will increase construction cost. Consequently, this article uses four main criteria to rank feasible PUP locations for development namely distance to slum neighborhood, accessibility, slope, and land value. Since the criteria used in this study were extracted in linguistic classes from original sources such as land value and slope, therefore triangular fuzzy number (TFN) was applied so that all criteria can be inputted commensurably into fuzzy TOPSIS.

Considering these four criteria for weighting and integration, AHP is suitable since it has been combined previously with GIS to search suitable location for urban green space development [4]. In addition to AHP, [5] combined intuitionistic fuzzy sets (IFS) with AHP which fits with judgement involving hesitancy, vagueness, dan intuition found in real world problem solving.

However, not all criteria have the same polarity, three criteria used in this study have negative polarity or the less the better, namely distance to slum, slope, and land value. On the other hand, accessibility criterion has positive polarity or the bigger the better. Speaking of multi-criteria ranking methods involving several public urban park location candidates with different unit of measurement, TOPSIS has the benefit to prioritize them based on the positive and negative ideal solutions [6]. It means that ranks resulted from TOPSIS, has put the top priority close to benefit criteria and far away from cost criteria, and this fits to solve the different polarity of involved criteria in this study.

Integration of all these criteria to prioritize locations for PUP development rank is crucially needed for the decision makers in Bogor Municipality to formulate the future budget and planning. Considering all of earlier mentioned benefits of GIS, intuitionistic fuzzy AHP (IF-AHP), and fuzzy TOPSIS to integrate multi-spatial criteria for location ranking, therefore the objective of this paper is to develop a model for PUP development priority in Bogor Municipality's feasible locations using GIS, IF-AHP, and fuzzy TOPSIS.

II. Methods

Overview of the methodology used in this paper can be observed in Fig. 1. For preparation, four spatial criteria in form of vector maps were created using ArcGIS. Land value and slope maps were originally available in linguistic classes from original sources, while distance to slum area was computed using network analysis tools in ArcGIS. Access to PUP was represented by the length of the adjacent road of PUP locations. Road length values were measured using path tool in Google Earth, after confirmed through the Google Earth's street view to observe whether a PUP location can be accessed by four-wheel vehicles. In fuzzy TOPSIS process, access was classified as benefit criterion while land value, slope, and distance to slum area as cost criteria. These criteria were processed to calculate their positive and negative ideal solutions.

These four spatial criteria were weighted using IF-AHP, where three landscape architects from Housing Agency in Government of Bogor Municipality were asked to provide expert judgment in form of pair-wise comparison matrix. The weights then used to generate weighted fuzzy positive and negative ideal solutions, and computed to provide distance to fuzzy positive (d_i^+) and fuzzy negative (d_i^-). Final calculation gives relative closeness coefficient value (CC_i) to each feasible PUP location so it can be ranked.

A. Study Area

Bogor Municipality consists of six sub-districts with 68 villages in lower level than sub-district. It is located

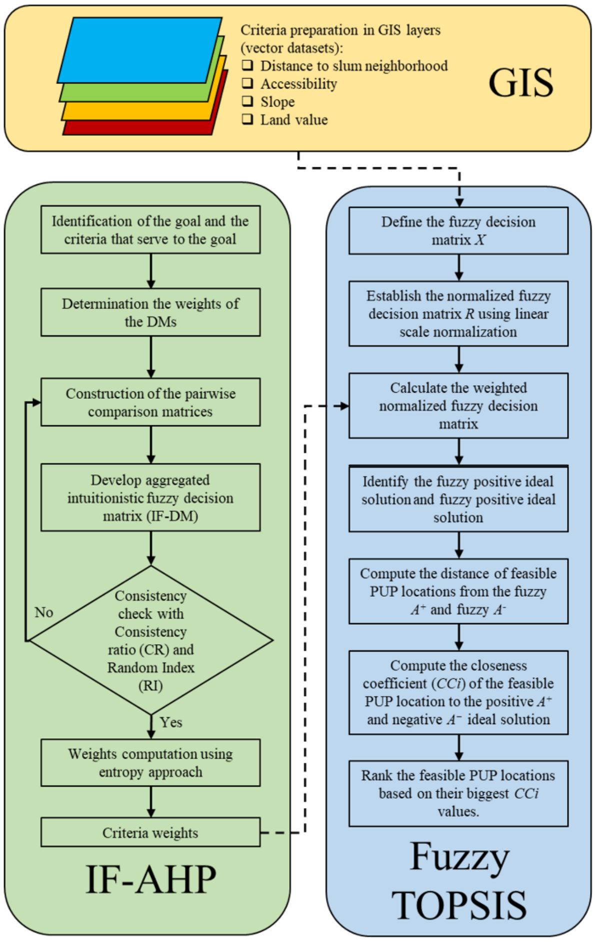

Fig. 1. Research flowchart

approximately 97.26 km from Bandung, the capital city of West Java Province. In September 2020, it has comparatively dense population of 1,043,070 people in area of 118.5 km^2 [7]. The city is located on the terrain with elevation between 190-330 m. Lowest averaged daily temperature is 20^o-34.2^{o}C. Monthly average rainfall is 267.9 up to 385.3 mm.

B. Criteria Preparation Using GIS

TFN in Fig. 3 [8] was used to convert four spatial criteria into fuzzy vector maps. PUP locations and slum neighbourhood were converted into centroids using ArcGIS to estimate the closest distance from each PUP to reach nearest slum neighborhood. Distance to slum neighborhood was regarded as the less the better, therefore when it bigger it will serve as the cost criteria. PUP locations in form of centroids were stored into a kml file and then uploaded into Google Earth software. In street view mode in Google Earth, actual road length can be observed in 3D photos and if the photos indicated a location can be accessed by four-wheel vehicles then road length was computed using path menu. This road length of each PUP location was input into ArcGIS spatial attribute and then converted into fuzzy value using TFN. For road length access, acquired crisp values were normalized using max method.

C. Intuitionistic Fuzzy AHP

According to [9] the intuitionistic fuzzy set (IFS) has the form:

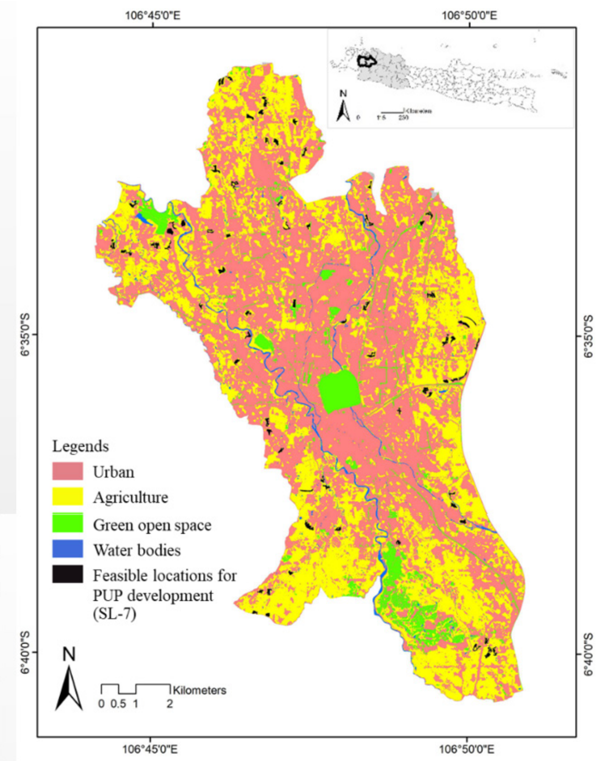

Fig. 2. Study area map (Source: modified from Landsat 8 2018 data processing, Government of Bogor Municipality datasets, and [1])

$$\{x, \mu_A(x), v_A(x) \mid x \in E\}, \tag{1}$$

where $\mu_A(x) \rightarrow [0,1]$ and $v_A(x) \rightarrow [0,1]$ represent the degree of membership. Membership degree of an element can be defined as:

$$0 \leq \mu_A(x), v_A(x) \leq 1$$
$$\{x, \mu_A(x), 1-\mu_A(x) \mid x \in E\}$$
$$\pi_A(x) = 1 - \mu_A(x) - v_A(x), \tag{2}$$

where $\forall x \in E$ in a set A. Here, $\pi_A(x)$ represents the hesitancy degree of membership of element x.

For implementation of IFS within AHP, this study uses following steps according to [5]:

1. Identification of the goal and the criteria that serve to the goal, the goal of this study is to prioritize feasible PUP locations for development in Bogor Municipality, hence four spatial criteria are needed to serve this goal, namely land value, accessibility, slope, and distance from slum neighborhood.
2. Determination the weights of the DMs, Let $D=\{D_1, D_2, D_3, ...D_k\}$ be the set of decision makers (DMs) where k indicates the number of DMs and λ_k denotes the influence weights of the DMs. In a previous study, [10] categories to weight experts' importance whom came from different backgrounds. Therefore, this study uses experts' importance weighting modified from [10]. For details, scoring values and categories can be observed in Table 1.

In order to process each score of each category commensurably among DMs, every score in each row was normalized using the following equation:

$$x' = \frac{x}{max_i}, \tag{3}$$

where x' = normalized score of each category in each DM while x = score of each category in each DM and max_i is the maximum score in each i-th row. Once weight of

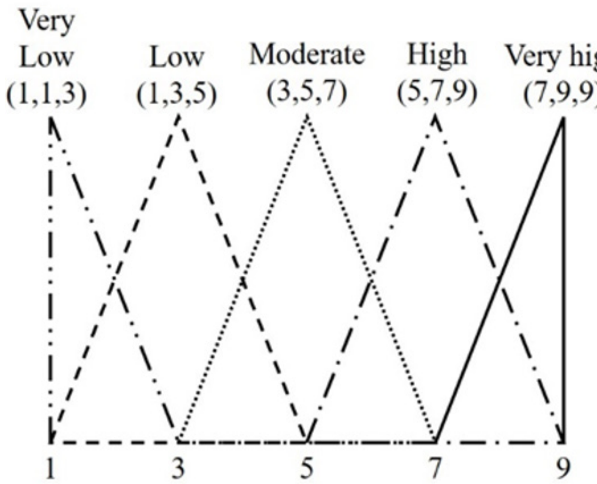

Fig. 3. Triangular Fuzzy Number (TFN) used in this paper

each expert is determined using characteristics in Table 1, it will be classified according to linguistic terms according in Table 2.

The yielded linguistic terms for every expert from Table 2 will the basis to compute expert' influence weight (λ_k) using the following equation:

$$\lambda_k = \frac{\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)}{\sum_{k=1}^{l}\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)},$$

where and (μ_k, v_k, π_k) are from IFNs in Table 2.

3. Construction of the pairwise comparison matrices where the value is given by each expert using linguistic terms referred to IFNs in Table 3.
4. Develop aggregated intuitionistic fuzzy decision matrix (IF-DM) using decision makers weight evaluation in equation 4. The following equation represents IFWA operator:

$$R_{ij} = IFWA_\lambda\left(R_{ij}^{(1)}, R_{ij}^{(2)}, R_{ij}^{(3)}, \ldots, R_{ij}^{(k)}\right) = \lambda_1 R_{ij}^{(1)} \oplus \ \lambda_1 R_{ij}^{(2)} \oplus \ldots \oplus \lambda_k R_{ij}^{(k)} = \left(1 - \prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_k}\right), \left(\prod_{k=1}^{K}\left(v_{ij}^{(k)}\right)^{\lambda_k}\right), \left(\prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_k} - \left(\prod_{k=1}^{K}\left(v_{ij}^{(k)}\right)^{\lambda_k}\right)\right), \quad (4)$$

where λ = { λ_1, λ_1,... λ_l}represents the weight of decision maker, and summation of all λ from all decision makers equal with 1 and $\lambda_k \in$ [0,1]. Herein,

Table 1. Experts' importance weighting (modified from [10])

Experts' characteristics	Category	Score
Achieved academic degree	Bachelor	1
	Master	2
	Doctoral	3
Years of experience in urban park location planning		Filled by expert
Membership of Indonesia's Professional Landscape Architet (IALI)	Yes	1
	No	0
Civil servant status	Permanent	1
	Contract	0

Table 2. Linguistic terms for importance weights of DMs

Linguistic terms	IFNs (μk, νk, πk)
Very unimportant	(0.10,0.80,0.10)
Unimportant	(0.25,0.60,0.15)
Medium	(0.50,0.40,0.10)
Important	(0.75,0.20,0.05)
Very important	(0.90,0.05,0.05)

$$R = \left(R_{ij}^{(k)}\right)\begin{bmatrix} R_{11}^{(k)} & R_{12}^{(k)} \ldots R_{1n}^{(k)} \\ R_{21}^{(k)} & R_{22}^{(k)} \ldots R_{2n}^{(k)} \\ \\ R_{m1}^{(k)} & R_{m2}^{(k)} \ldots R_{mn}^{(k)} \end{bmatrix},$$

and $R_{ij}^{(k)} = \{\mu_{ij}^{(k)}, v_{ij}^{(k)}, \pi_{ij}^{(k)}\}$, where $k \in K$, and (i=1,2,…,m; j=1,2,…,n).

5. Consistency check with Consistency ratio (CR) and Random Index (RI) are conducted in this checking. The formula of CR is described in the equation 5:

$$CR = \frac{RI - \frac{\sum \pi_{ij}}{n}}{n-1}. \quad (5)$$

In addition, RI value is referred to [11] where its values varied according to specific number of criteria (n). RI values are described in Table 4.

6. Weights computation using entropy approach as described in the following equations:

$$\overline{\overline{w_i}} = -\frac{1}{n\ln 2}\left[\mu_i \ln \mu_i + v_i \ln v_i - (1-\pi)ln(1-\pi_i) - \pi_i ln2\right] \quad (6)$$

Table 3. Linguistic terms for pairwise comparison matrices [5]

Linguistic variables for pairwise comparison	Preference Numbers	IFNs
Equally Important	1	(0.02, 0.18, 0.80)
Intermediate Value	2	(0.06, 0.23, 0.70)
Weakly More Important	3	(0.13, 0.27, 0.60)
Intermediate Value	4	(0.22, 0.28, 0.50)
Strongly More Important	5	(0.33, 0.27, 0.40)
Intermediate Value	6	(0.47, 0.23, 0.30)
Very Strong More Important	7	(0.62, 0.18, 0.20)
Intermediate Value	8	(0.80, 0.10, 0.10)
Absolutely More Important	9	(1.00, 0.00, 0.00)
Reciprocals	Preference Numbers	IFNs
Equally Important	1	(0.18, 0.02, 0.80)
Intermediate Value	1/2	(0.23, 0.06, 0.70)
Weakly More Important	1/3	(0.27, 0.13, 0.60)
Intermediate Value	1/4	(0.28, 0.22, 0.50)
Strongly More Important	1/5	(0.27, 0.33, 0.40)
Intermediate Value	1/6	(0.23, 0.47, 0.30)
Very Strong More Important	1/7	(0.18, 0.62, 0.20)
Intermediate Value	1/8	(0.10, 0.80, 0.10)
Absolutely More Important	1/9	(0.00, 1.00, 0.00)

Table 4. Random index per number of criteria [11]

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

$$w_i = \frac{1-\overline{\overline{w_i}}}{n-\sum_{j=1}^{n}\overline{\overline{w_i}}},\ where\ \sum_{j=1}^{n} w_i = 1\ . \quad (7)$$

D. Fuzzy TOPSIS

The steps of Fuzzy TOPSIS in this article was performed to integrate the weighted resulted from IF-AHP and multi-spatial vector maps using the fuzzy ideal negative and positive solutions. There are specific reasons to use Fuzzy TOPSIS in this article:

1. The original vector map of land value zone was accessed from the National Land Agency Republic of Indonesia website (https://bhumi.atrbpn.go.id) in form of categorical values, therefore the other vector maps needed to be converted into fuzzy scale;

2. Though the primary actors of PUP land acquisition in Bogor Municipality are employees in Housing Agency, the final decision still have to wait the approval letter from Regional Planning Agency and Government Asset Agency stating that sitting location is clean and clear from the perspective of future masterplan and no overlapping government asset;

3. Given the various locations in form of vector map, integration of weights from AHP, fuzzy criteria values and positive negative solutions in every location can be done in tabular spatial attribute.

For this study all of the fuzzy TOPSIS computation was performed using various function within attribute table menu in ArcMap 10.3, the following steps of fuzzy TOPSIS are described based on [12]:

1. *Define the fuzzy decision matrix X* :

$$X = \left(x_{ij}\right)_{m\times n}, \quad (8)$$

where $x_{ij} = (a_{ij},b_{ij},c_{ij})$.

2. *Establish the normalized fuzzy decision matrix R using linear scale normalization:*

$$R = r_{ij\ m\times n}, \quad (9)$$

here, i=1,2,3,…,m and j=1,2,3,…,n.

$$r_{ij} = \left(\frac{a_{ij}}{c_j^+},\frac{b_{ij}}{b_j^+},\frac{c_{ij}}{c_j^+}\right), \quad (10)$$

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}},\frac{a_j^-}{b_{ij}},\frac{a_j^-}{a_{ij}}\right). \quad (11)$$

3. *Calculate the weighted normalized fuzzy decision matrix:*

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}},\frac{a_j^-}{b_{ij}},\frac{a_j^-}{a_{ij}}\right), \quad (11)$$

here, $v_{ij} = r_{ij} x\ w$.

4. *Identify the fuzzy positive ideal solution and fuzzy positive ideal solution:*

$$V = \left[v_{ij}\right]_{m\,x\,n}, \quad (12)$$

V_j^+ = max v_{ij} if ($j \in J$); min v_{ij} if ($j \in J'$)
where j = 1,2,3,…,n.
Fuzzy negative ideal solution:

$$A^+ = \left(v_1^+,\ v_2^+,\ v_3^+,\ \ldots,v_4^+\right), \quad (13)$$

V_j^- = max v_{ij} if ($j \in J$); min v_{ij} if ($j \in J'$)
where j = 1,2,3,...,n.

5. *Compute the distance of feasible PUP location from the fuzzy A^+ and fuzzy A^- using the following equations*:

Distance from fuzzy positive ideal solutions A^+:

$$A^- = \left(v_1^-,\ v_2^-,\ v_3^-,\ \ldots,v_4^-\right), \quad (14)$$

where, j = 1, 2, 3, . . . , m.

Distance from fuzzy negative ideal solutions $A-$:

$$A^- = \left(v_1^-,\ v_2^-,\ v_3^-,\ \ldots,v_4^-\right), \quad (14)$$

where, j = *1, 2, 3, . . . , m.*
Here, the distance between two fuzzy numbers $A = (x_1, x_2, x_3)$ and $B = (y_1, y_2, y_3)$

$$d\left(A,B\right) = \sqrt{\frac{1}{3}\left(\left(x_1-y_1\right)^2+\left(x_2-y_2\right)^2\left(x_3-y_3\right)^2\right)}\ . \quad (17)$$

6. *Compute the closeness coefficient (CC_i) of the feasible PUP location to the positive A^+ and negative A^- ideal solution*

$$CC_I = \frac{d_i^-}{d_i^+ + d_i^-}, \quad (18)$$

where, i = 1, 2, 3, . . . , m; d^+_i is the distance from the fuzzy positive ideal solution and d^-_i is the distance from the fuzzy negative ideal solution.

7. *Rank the feasible PUP locations based on their biggest CC_i values. The first priority for PUP development is the feasible location with the furthest distance from negative A^- and the closest distance from positive A^+. In ArcGIS, this operation can be performed using sort function within attribute table* (see Fig. 4).

III. Results

A. Criteria Maps

Based on mentioned methods earlier to prepare criteria maps needed for this study, all of PUP locations in form of point vector data are shown in Fig. 5. In Fig. 5(a), classes of distance to slum neighborhood are displayed in five colors. Moreover, map of accessibility classes is shown in Fig. 5(b), where interestingly there is no very low accessibility class in Central Bogor sub-district.

It can also be added that all sub-districts but Central Bogor sub-district have locations with very low accessibility though it does not mean that very low accessibility cannot be accessed by four-wheel vehicle as explained in criteria preparation. As for the slope classes, a map in Fig. 5(c) shows that nearly all locations have very gently slope. In addition, the land value of feasible locations for PUP development is displayed in four classes within Fig. 5(d). For Fig.s 5(c) and 5(d), displayed classes are not five but depend on where the locations fall within class range, for example in Fig. 5(d), there is no location within the best land value or in other words no feasible location for PUP development has lowest value range.

B. Criteria Weights from IF-AHP

Firstly, all DMs importance weights were scored using categories from Table 1. In each category, the score for each DM was normalized using equation 3. For instance, DM A has master degree level of education therefore DM A had a score of 2 but because it was normalized using equation 3, hence DM A has normalized score of 1 as can be seen in Table 5. The final result indicates that DM A is very important followed by DM B with important, and DM C has medium importance weight.

For further computation, influence weight of each DM (λ_k) is needed to be calculated using equation (4). As DM A is very important therefore according linguistic terms in Table 2, DM A has IFN of (0.90,0.05,0.05). When its IFN of DM A was inputted into equation 4, therefore λ_A = 0.9+(0.05*(0.9/(0.9+0.05))) = 0.95. When normalized with the sum other experts' influence weight, hence the final λ_A weight become 0.41.

The next step is to gather experts' preference number for pairwise comparison. Herein, three DMs were sent forms to be filled with preference numbers and later converted into IFNs according to Table 3.

All of experts' preference numbers in pairwise comparison within Table 6 were integrated using IFWA in equation 4. For example to determine r_{12} within R matrix, the value from Table 6 for each DM in designated for first column and second row where DM A (1/7), DM B (1/3), and DM C (1/9). Hence, their IFNs can be linked with Table 3, and be converted as DM A (0.18, 0.62, 0.20), DM B (0.27, 0.13, 0.60), and DM C (0.00, 1.00, 0.00). These values were computed using equation (4) to yield μ_{ij} between C_2 in second row and C_1 in first column, and the computation process can be described as (1-((1-0.18)$^{0.41}$*(1- 0.27)$^{0.35}$*(1-0)$^{0.24}$)= 0.17. Thus, it can be observed in Table 7 that the μ_{ij} in r_{12} is 0.17. The whole resulted matrix R can be observed in Table 7.

For consistency check, equation 5 was applied with input of π_{ij} in Table 7. It can be described that π_{ij} = 5.98 and RI according to Table 4 is 0.9 (n=4). Therefore CR = (0.9- (5.98/4))/(4-1) = -0.198. Thus, CR value ≤ 0.1 and fulfill the requirement of consistency check.

Furthermore, by applying equation 6 and 7 the weights of criteria for prioritizing PUP development in feasible location can be determined. Hence, $w_{accessibility}$= 0.261, $w_{land\ value}$= 0.259, $w_{distance\ to\ slum}$ = 0.255, and w_{slope}= 0.225. These weights are used for further computation within fuzzy TOPSIS.

The fact that IF-AHP method in this study yields in highest weight for accessibility, it indicates that experts from urban park planners put access to feasible location

access	norm_acces	max_access	Rij_pstv_l	Rij_pstv_m	Rij_pstv_u
336.84	0.96	4	0.56	0.78	1
121.92	0.35	2	0.11	0.33	0.56
20.99	0.06	1	0.11	0.11	0.33
21.72	0.06	1	0.11	0.11	0.33
4.33	0.01	1	0.11	0.11	0.33
5.85	0.02	1	0.11	0.11	0.33
55.29	0.16	1	0.11	0.11	0.33
2.77	0.01	1	0.11	0.11	0.33
72.58	0.21	1	0.11	0.11	0.33
246.48	0.7	3	0.33	0.56	0.78
351.35	1	5	0.78	1	1
13.62	0.04	1	0.11	0.11	0.33
4.15	0.01	1	0.11	0.11	0.33
26.97	0.08	1	0.11	0.11	0.33
6.2	0.02	1	0.11	0.11	0.33

Fig. 4. The process of fuzzy TOPSIS using attribute table menu in ArcMap 10.3

as prerequisite before starting procurement or even development. From several previous studies, accessibility is emphasized as factors to determine suitable locations for urban green space or urban park ([3], [13]). Hence, it is acceptable for this study that accessibility has the highest weight considering its vital role to access the PUP locations.

As land value criterion gains second place weight based on IF-AHP, it indicates that feasible locations for PUP development need to be purchased first by the Government of Bogor Municipality. The land value for PUP development is very important because budget to

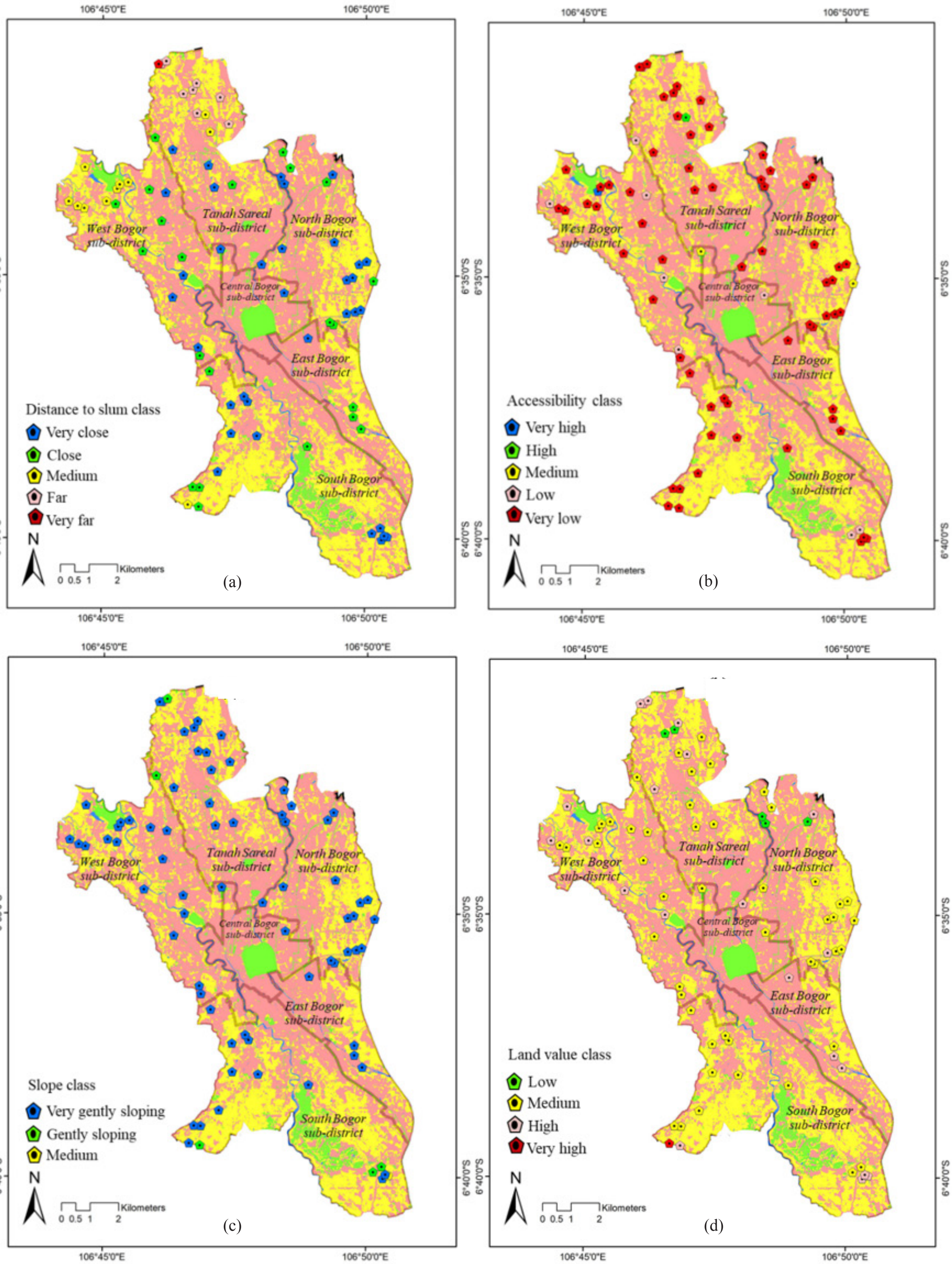

Fig. 5. PUP locations: (a) distance to slum neighborhood class, (b) accessibility class, (c) slope class, and (d) land value class

Table 5. DMs' importance weights

Expert's criteria	Category	Scores	A	B	C	A'	B'	C'
Achieved academic degree	Bachelor	1	-	1	1	1	0.5	0.5
	Master	2	2	-	-			
	Doctoral	3	-	-	-			
Years of experience	Years	Filled by experts	13	5	6	1	0.38	0.46
Membership of Indonesia's Landscape Architect Association (IALI)	Yes	1	1	1	1	1	1	1
	No	0	-	-	-			
Permanent civil servant status	Yes	1	1	1	-	1	1	0
	No	0	-	-	0			
Sum						4	2.88	1.96
Normalized weight						1	0.72	0.49
Weight classification						Very important (1-0.8)	Important (0.79-0.6)	Medium (0.59-0.4)

Table 6. Pairwise comparison matrix

DM A	Distance to slum (C1)	Accessibility (C2)	Slope (C3)	Land value (C4)
Distance to slum	1	7	1/5	1/8
Accessibility	1/7	1	1/8	1/5
Slope	5	8	1	1/9
Land value	8	5	9	1
DM B	**Distance to slum (C1)**	**Accessibility (C2)**	**Slope (C3)**	**Land value (C4)**
Distance to slum	1	3	2	1/6
Accessibility	1/3	1	5	3
Slope	1/3	1/5	1	¼
Land value	6	1/5	6	1
DM C	**Distance to slum (C1)**	**Accessibility (C2)**	**Slope (C3)**	**Land value (C4)**
Distance to slum	1	9	1/5	9
Accessibility	1/9	1	1/5	9
Slope	5	5	1	5
Land value	1/9	1/9	1/5	1

Table 7. Aggregated IFNs and criteria weights

Criteria	**Distance to slum (C1)**			**Accessibility (C2)**			**Slope (C3)**			**Land value (C4)**				***Wi***
	μij	vij	πij	μij	vij	πij	μij	vij	πij	μij	vij	πij		
Distance to slum (C1)	0.02	0.18	0.80	1.00	0.00	0.00	0.27	0.33	0.40	1.00	0.00	0.00	0.258	0.255
Accessibility (C2)	0.17	0.41	0.42	0.02	0.18	0.80	0.23	0.44	0.33	1.00	0.00	0.00	0.242	0.261
Slope (C3)	0.31	0.21	0.48	0.58	0.19	0.23	0.02	0.18	0.80	0.19	0.43	0.38	0.345	0.225
Land value (C4)	0.59	0.23	0.18	0.24	0.40	0.36	1.00	0.00	0.00	0.02	0.18	0.80	0.246	0.259

purchase feasible location needs to be planned first and consulted with people's representatives in the parliament. This can be a major constraint for urban park planners and decision makers in Bogor Municipality considering that according to [14] the land value in Jabodetabek has extremely high growth when compared to other cities in Indonesia and some other cities in Asia.

As one of the ultimate goals for PUP development in Bogor Municipality to serve closer to the mostly needed communities such as slum neighborhood and poor societies, distance to slum neighborhood is considered as crucial criteria to prioritize the development of feasible PUP locations.

C. PUP Development Priority

The spatial distribution of PUP feasible locations development priority based on CC_i value is displayed in Fig. 6. The priority classes were generated using equal interval method in ArcMap 10.3, namely very high, high, medium, low, and very low. Very high priority means that feasible locations within this class are very urgently to be constructed for PUP based on closesnest to slum neigborhood, better accessibility, gentle slope, and better land value. Interestingly, as it can be observed in Fig. 6 there is no feasible location for PUP development in Central Bogor sub-district with CC_i value within very high priority class. It can be caused by its distance to slum areas where it is farther than other locations, not to mention the higher land value. Furthermore, some of very low priority locations in the northern Bogor Municipality in Fig. 6 correspond with distance from slum neighborhoods in Fig. 5(a).

Since most of the feasible locations have similar value range in accessibility and slope criteria as can be seen in Fig.s 5(b) and 5(c), it can be interpreted that these two criteria give no substantial change for PUP development priority. On the contrary, distance to slum and land value criteria shown in Fig.s 5(a) and 5(d) have more different values among feasible locations. It can be sumarized that distance to slum and land value are two criteria which provide more influential to CC_i value in each feasible location when compared to accessibility and slope.

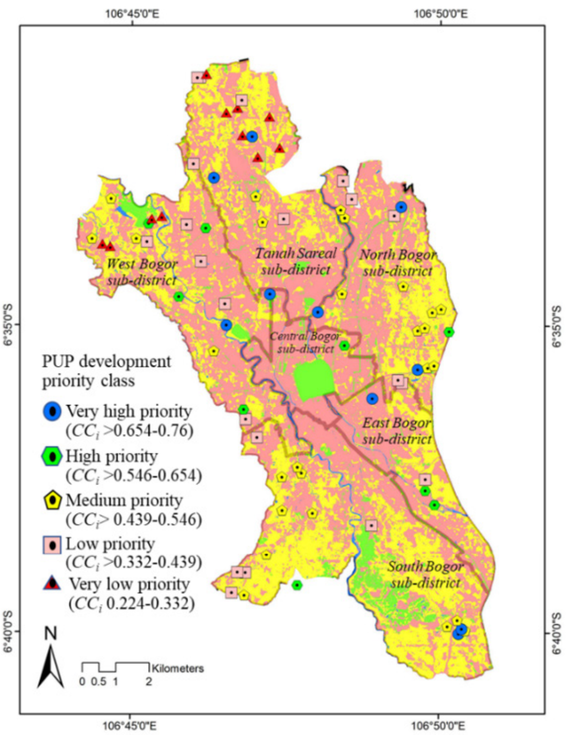

Fig. 6. Priority classes for PUP development

For area calculation in each priority class, very high priority class has around 0.14 km^2, while high priority class has approximately 0.12 km^2. As it can be observed in Fig. 7(a), medium priority class has the biggest area around 0.38 km^2, followed by low priority class with 0.29 km^2. Based on the official area of Bogor Municipality around 118.5 km^2, the total area of feasible location for PUP development is around 1.076 km^2 or 0.91% of the Bogor Municipality.

It can be observed in Fig. 7(b) that very high class priority provides 10 locations for PUP development, while medium class priority consists of 26 locations. In total, there are 77 feasible locations for PUP development.

IV. Discussions

Results gained in form of priority classes for PUP development in feasible locations within this study have given decision makers a clear map for options. Plus, it gives decision makers abundance of location alternatives for PUP development in Bogor Municipality. When problems might arise within locations of very high priority which can prevent PUP construction, decision makers have choices of feasible locations in high or medium priority classes. And since its locations are scattered in all of six sub-districts, the development of PUP in these feasible locations might satisfy the population in each sub-district. From the perspective of tackling the problems in slum areas, these feasible locations of PUP development add to the existing efforts performed by the Government of Bogor Municipality and central government to improve slum areas such as *KOTAKU* (*Kota tanpa kumuh*) and *BSPS* (*Bantuan stimulan perumahan swadaya*).

The superiority of applied fuzzy TOPSIS in this study is reflected by the results of this study where priority ranks

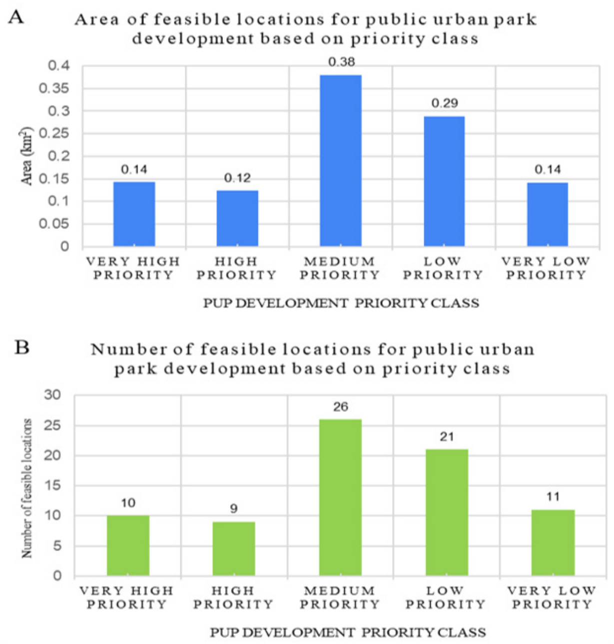

Fig. 7. PUP development priority class based on: (A) area, and (B) number of locations for public urban park development

for the feasible locations of PUP development approach the closest distance for positive solutions such as accessibility and stay away from negative solutions such as land value. Though in previous studies ([15], [3]), combination of AHP and TOPSIS with multi-criteria of GIS has successfully provided alternatives in searching location of urban parks and green spaces, but further special technique is needed when tackling the fuzziness of multi-spatial criteria found such as in this study. Furthermore, this study considers hesitancy and vagueness of experts' judgement through IF-AHP method beside the fuzziness of multi-spatial criteria which processed using GIS and fuzzy TOPSIS.

However, for further implementation of this result an updated ground checking is needed to anticipate recent land use changes. In addition, real construction development program should be based on available budget and therefore further study related to actual size of each location should be performed to plan the detail engineering design and eventually construction budget.

V. Conclusion

The combination of GIS, IF-AHP, and Fuzzy TOPSIS has succesfully resulted five priority classes of feasible locations for PUP development in Bogor Municipality. The very high priority class which has the biggest CC_i values range (>0.654-0.76) provides 0.14 km^2 area of feasible PUP development with 10 locations. The biggest area for PUP development is generated by medium priority class with 26 feasible locations and approximately area of 0.38 km^2.

Acknowledgment

This study does not represent the policy of the Government of Bogor Municipality, and therefore this paper is purely intended for academic purpose.

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