Gis- Based Land Suitability Analysis Using AHP for Public Parks Planning in Kota Bharu, Kelantan

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Abstract

Optimal locations for public facilities, such as public parks, are significant issues in the urban planning of Kota Bharu, Kelantan. Therefore, specifically, Kota Bharu, Kelantan was selected as the study area where the land suitability model was applied to determine suitable land for public parks. This study was carried out within the framework of an Analytic Hierarchy Process (AHP) as a multi-criteria evaluation approach by integrating it with the Geographic Information System (GIS). The IDRISI GIS package was used to calculate the weights based on four alternative scenarios. Computed composite weights were inserted into the spatial analysis function of the GIS and produced four scenarios of suitability maps, i.e.: (a) population density, (b) existing public parks, (c) industrial area and, (d) land availability. Hence, based on the analysis and findings made in this research, finding suitable locations using the land suitability model for future park development is highly helpful. The results can be useful in the planning of public facilities and future land use planning in Kota Bharu, Kelantan.

Keywords: GIS, AHP, Parks, Land suitability, Optimal location

1.0 Introduction

A public park is an essential element in a city that serves as an outdoor recreational place for the community. It helps in generating the economic and social values and promoting a healthy lifestyle for the local community. The design, operation and maintenance is usually carried out by the government, typically on the local level, but may occasionally be contracted out to a private sector company (Girling and Helphand, 1997). Parks are classified into two major categories, such as the provision of recreation, services to society and conservation of natural values (Maruani and Amit-Cohen, 2007). A park is an open space, area of natural, semi-natural, or planted space set aside for human enjoyment and recreation or for the protection of wildlife or natural habitats. Common features of public parks include playgrounds, gardens, hiking, running and fitness trails or paths, bridle paths, sports field and courts, public restrooms, boat ramps and/or picnic facilities, depending on the budget and natural features available. In this paper, the terms 'open space', 'green space' and 'public park' were used interchangeably and presumed to be synonymous.

Open spaces and green spaces are important components of urban environments and they can improve and ameliorate microclimates, reduce air pollution, and alleviate heat island effects, provide comfortable recreational space for residential areas and contribute to sustainable urban environments (Carr, 1992; Dudek, 2000; and Hagla, 2008). Qelichi M. et al. (2012), paving the way for enjoying aesthetic chances (Kong et al., 2007). Thus, it can be said that as a part of the urban space with enriched environmental, skeletal, social and cultural dimension parks, open spaces and the urban environment play social, economic and ecological roles. In addition, taking advantage of the capacity of treating psychological diseases, open spaces can provide a favourable environment for rearing children, developing social integration, keeping tranquility, they are also considered as an indicator for improving the life space quality and social development (Balram, 2005; Sarvar, R. et al., 2011; and Chiesura, 2004). Undoubtedly, the open spaces must be sorted as the most basic factors effective in maintaining the natural and human dimensions of life in the contemporary world (Sarvar, R. et al., 2011).

In Malaysia, a public park is considered as an open space which is an important non-renewable component of landscape planning. According to the Department of Town and Regional Planning under the Town and Regional Planning Act (Amendment) 1995 (A933), open space is defined as any land either gated or not, which had been specifically and fully reserved or a part of it, to be used as a garden, public park, football field, public recreation area or as a public place. Also, the hierarchy and characteristic (size and catchment area) of an open space can be

classified as a national park (no limitation on size, all countries), regional park (100 hectares, all regions), town park/urban park (40 hectares, 50,000 people and above), local park (8 hectares and above but not to exceed 40 hectares, 12,000 to 50,000 people), neighbourhood park (2 hectares and above but not to exceed 8 hectares, 3,000 to 12,000 people), playing field (0.6 hectares and above but not to exceed 2 hectares, 1,000 to 12,000 people) and playlot (0.2 hectare and below, 300 to 1,000 people) (JPBD, 2000).

City parks and recreation departments are responsible for deciding the amount of land for parks, the number of parks, and the size of parks within the area of a city. Under the National Urbanisation Policy (NUP) prepared by the Department of Town and Country Planning, Peninsular Malaysia (JPBD), a target for open spaces was adopted. One of the measures identified under the policy (NUP9.ii) is to provide adequate public open spaces through adopting the standard of two hectares per a 1,000 urban population. This standard is also contained in Murni.net indicators for assessing a sustainable city. The policy also calls for recreational areas to be gazetted and for their development to be monitored, for environmentally sensitive areas to be protected and for green areas to be established as buffer zones to limit urban development (Rusli and Ludin, 2010).

In many countries, open spaces are nowadays regarded as an integral part of land use planning decisions. The provision of public open space has to be planned and realised together with the planning of other urban functions like housing, transport, infrastructure, etc. However, approaches to open space planning vary, and there is no general agreement on the desirable planning criteria as to how much open space is needed, where open space should be located or how it should be used (Maruani and Cohen, 2007). Without careful urban land use planning, urban green and open spaces will be filled with residential and commercial buildings to cater for rapid development growth. Therefore, there is a need for proper planning control to ensure that the provisions of open spaces are adequately being conserved for current and future generations.

The necessity to develop new urban applications, essential to meet the ever-increasing needs of citizens, gradually has decreased the share of open spaces in the cities which in turn is followed by the limited urban population's accessibility to nature (JPBD, 2002; Sarvar, R. et al., 2011). Aspects such as "amount of public open space per inhabitant", "public parks" and "recreation areas" are often mentioned as important factors to make the city liveable, pleasant and attractive for its citizen's (Qelichi M. et al., 2012). Developers should provide ten percent of open space and recreational areas for all types of residential, commercial, industrial, mixed-use, tourism and institutional development with a minimum requirement of 0.2 hectares (JPBD, 2000). However, the current layout of open space in most areas tends to be the result of opportunistic provision, rather than a planned approach, and will often not reflect current population densities nor provide an equitable distribution of facilities (Rusli and Ludin, 2010). In addition, a number of studies have shown that the location of the open space is usually not based on scientific analysis thus, attention to problems of public parks provision is necessary (Qelichi M. et al., 2012). There is much to be desired of the quality of these spaces as the developers' notion of open spaces often means 'leftover spaces'. Therefore, the main objective of this paper is to balance the loss of open space by creating a replacement in the form of a public park in Kota Bharu Municipal Council by finding the most optimal and suitable site to locate the public park based on an integrated GIS multi-criteria evaluation technique.

2.0 Study Area

The study area is an area under the administrative unit of Kota Bharu Local Authority or Majlis Perbandaran Kota Bharu, Kelantan (MPKB) as exhibited in Figure 1. Kota Bharu has become one of the key components of development in Kelantan as the highest density of population concentration compared to other districts. The complexity of the development issues and the increase of population are seemingly the fundamental issues that contribute to the environmental sustainable matters, in the study area, of life towards the sustainable livelihood in the Kota Bharu Municipality. Kota Bharu is chosen as it is the capital city of Kelantan which still has abundance of undeveloped land to be developed as public parks compared to other major cities in Malaysia. It is believed that the presence of sufficient green space areas with adequate accessibility in the city contributes to the happiness of the citizens towards a sustainable quality of life.

Table 1: The Need for Open Spaces. Source: JPBD (2005)

Year	Total population	The need for Open Space (ha)	Population increase (Projection)	The proposal for new open space (ha)
2010	336, 200	672.4	10,490	19.95
2015	359, 880	719.76	23,680	47.36
2020	394, 330	788.66	34,450	68.76

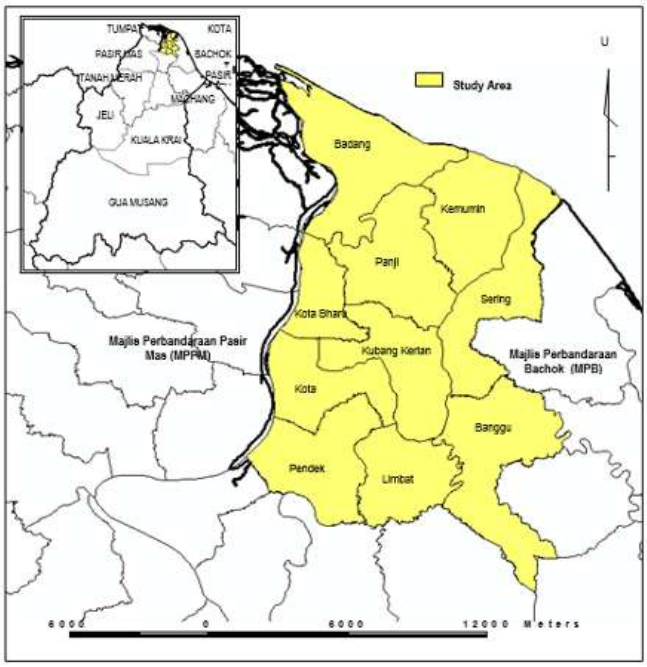

Figure 1. Study Area

3.0 Methodology

In this research, the evaluation of the required criteria for the location of parks was an attempt to create maps and data layers for each of the criteria in the GIS. The GIS plays a vital role in planning for many decades of land-use suitability mapping and modelling (Malczewski, 2004 and Malczewski, 2006). Then for modelling, each data layer was assigned a weight based on the AHP model. Maps with the overlay method were combined together and using the multi-criteria decision-making (MCDM) techniques, the best place for parks in the case study area was proposed (Aragonés-Beltrán, Chaparro-González, Pastor-Ferrando & Pla-Rubio, 2014). The AHP is a systematic method to guide decision-makers in making decisions to solve the problems based on priorities (Miller et al., 1998). This paper addresses a scientific approach to determine suitable land for healthy urban development. This approach will help in the revision of policy and preparation of development plans in the study area and for other cities as well. Based on the issue and problem that were discussed previously, the objectives to be achieved in this study are i) mapping the existing open space area, ii) determine the adequate open space through adopting the standard of two hectares per 1,000 urban population suitable land, and iii) determine the most optimal and suitable site to locate the public park based on an integrated GIS multi-criteria evaluation technique (Figure 2).

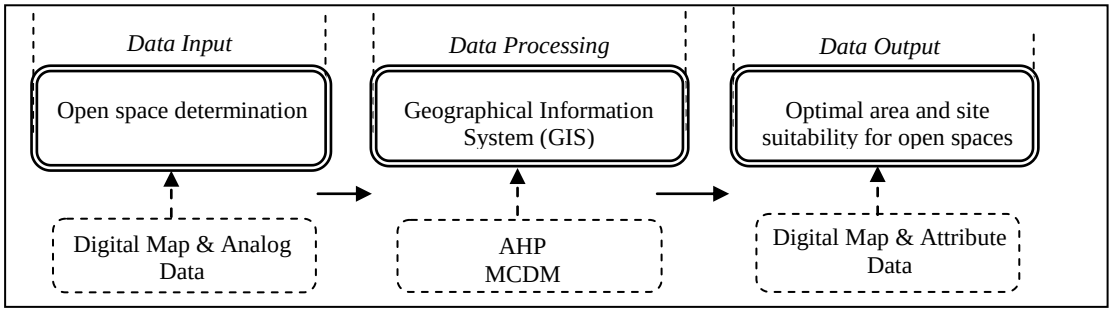

Figure 2: Conceptual diagram

3.1 Data collection

The spatial and non-spatial data was collected from the department of Town Planning, municipal authorities of Kota Bharu, Kelantan. It was easy to get data through formal requests. There were some limitations, e.g., time constraint and sensitive area information.

3.2 GIS data base development

The GIS data base development of this study was developed by using the criteria and sub-criteria that is indicated in Table 2. The base map of Kota Bharu was scanned and geo-referencing was fixed to change it into earth coordinates, then it was digitised in ArcGIS 9.2 software to develop the data layers.

3.3 Development of the pairwise comparison matrix

Matrixes of pairwise comparisons were created by the experts on condition that judgments were evaluated to find suitable alternatives to estimate associated absolute numbers from 1 to 9, the fundamental scales of the AHP (Saaty, 2007) exhibited in Table 2. Four alternative scenarios were produced by using the AHP in the suitable site selection of parks.

Table 1. The Scenario of Suitability Maps. Source: JPBD, 2000

Scenarios	**Parametres**	
Social	Population Density (kernel density estimation)	High Medium Low
Accessibility	Major roads Local roads	< 1000 metres > 1000 metres
Land use	Existing parks	< 1000 metres > 1000 metres
	Industrial area	Heavy < 500 metres Medium < 250 metres Light < 50 metres
Land Availability	Vacant land	

Table 2. AHP Scale of Relative Importance. Source: Saaty (1985)

Intensity of relative importance	Definition	Explanation
1	Equal importance	Two activities combine equally to the objective.
3	Moderate importance of one over another	Experience and judgment slightly favour one activity over another.
5	Essential or strong importance	Experience and judgment strongly favour one activity over another.
7	Demonstrated importance	An activity is strongly favoured and its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible order of affirmation.
2, 4, 6, and 8	Intermediate values between the two adjacent judgments	When compromise is needed.

3.4 Computation of the pairwise comparison matrix

Table 1 exhibits the criteria and sub-criteria, considered in the land suitability analysis to create four alternatives (scenarios) by using the ArcGIS 9.2 spatial analysis tool. The weights of factors and parametres were successfully calculated easily for land suitability with the Idrisi Kilimanjaro software (keeping in view the consistency ratio (CR) (Figure 3). If the CR was satisfactory, it did not exceed the desired range, i.e., >0.10. If the CR value was in an undesirable range, the obtained judgement matrix needed to be reviewed till these values improved were satisfactory.

Later on, to compute the composite weights, Eastman et al., 1995 stated two procedures for multi-criteria evaluation: the concordance discordance analysis and the weighted linear combination. The function of a weighted linear combination (WLC) procedure where each factor and parametre (Vi) are multiplied by the weight of the suitability parametres (Wi) to get composite weights. WLC is a straight forward linear method calculating composite weights. Similarly, the results of composite weights based on alternatives (scenarios) are used in a

weighted sum spatial analysis function. This function multiplies and sums up the layers to produce scenario suitability maps for parks by the following formula:

$$E = \sum_{i=1}^{n} wi * vi$$

Where: Wi = relative importance or weight of factors/parametres i, Vi = relative weight of parametres i, and n = total number of parametres related to the study.

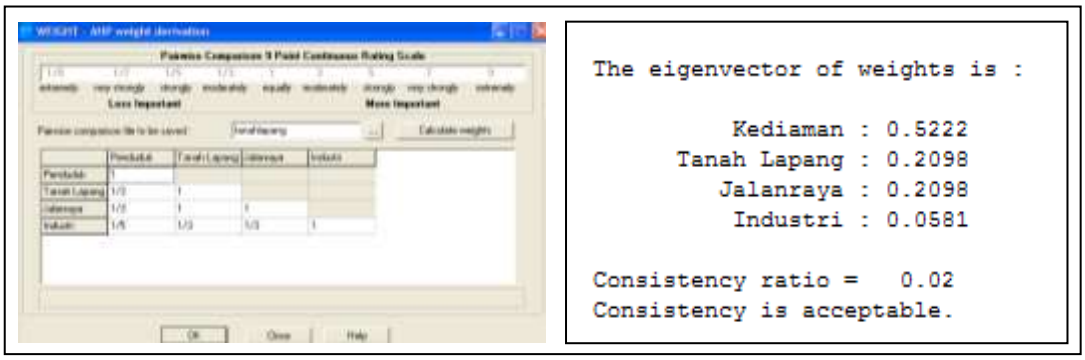

Figure 3: The weights of factors and parametres calculated and consistency ratio

4.0 GIS based Land Suitability Analysis

The land suitability analysis was performed in the raster format. The raster data model is the more suitable technique because the structure of raster data is grid cell based, which can easily delineate suitable sites. Raster data facilitates the user in carrying out a weighted overlay on numerous layers. Suitability maps were created under a raster GIS environment, based on various scenarios. The suitability for each land use was analysed in ArcGIS 9.2 to locate suitable areas for parks.

5.0 Results and Discussion

The AHP method is used to evaluate weight of each factor and sub-criteria (parameters). The AHP and the Geographic Information System (GIS) are integrated to assess suitable land for public parks in Kota Bharu for the year 2015 and the year 2020 (Figure 4 and Figure 5).

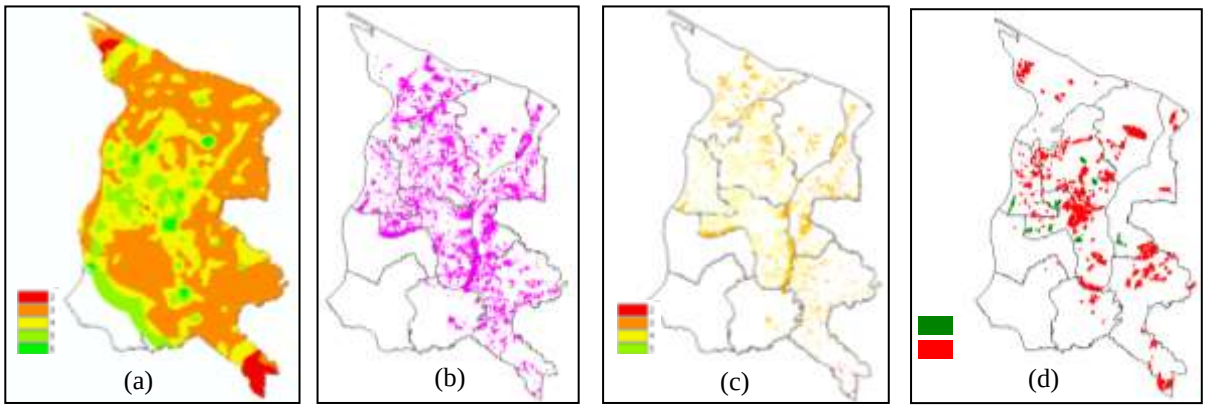

Figure 4 (a): Weighted overlay (determine potential land), (b): Land availability, (c) Intersect of land suitability and land availability, and (d): Land suitability for new public park in 2015

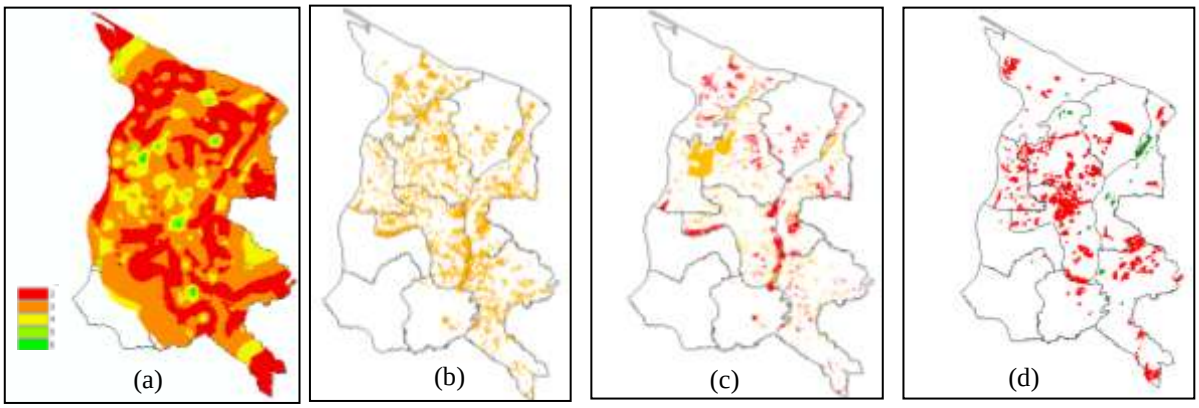

Figure 5 (a): Weighted overlay (determine potential land), (b): Land availability, (c) Intersect of land suitability and land availability, and (d): Land suitability for new public park in 2020

6.0 Evaluation of potential land based on scenarios

All four scenarios were combined to determine potential land. As stated in Figure 4 (a) 0.9%; of the area was ranked by a suitability value 6, 11.5 % with a suitability value 5, 30.6% with a suitability value 4 and 54.7% with a suitability value 3. The total population projection for the year 2015 is 359, 880 people and the estimation of the need to open space and recreation in that year is 719.76 hectares. Priority has been given to areas with the highest suitability value and in regards to land availability (Figure 4 (b)), to the proposed new public park with 47.36 hectares (Figure 4 (d)).

The weighted overlay of all criteria including the distance to the proposed new public park in 2015 produced the suitability map for the year 2020 (Figure 5 (a)). The total area 0.26% ranked by a suitability value 6, 1.1% ranked by a suitability value 5, 47.8% ranked by a suitability value 4 and 36.6% ranked by a suitability value 3. The total population projection for the year 2020 is 394, 330 people and the estimation of the need to open space and recreation in that year is 788.66 hectares. Priority has been given to areas with the highest suitability value and in regards to land availability (Figure 4 (b)), to the proposed new public park with 47.36 hectares (Figure 5 (d)).

Finding an optimal and proper location for various urban uses and urban service rendering centres will decrease costs, on the one hand, and will increase quality of services and hence, the efficiency rate. Inter alia, the urban parks, as the most open and public spaces of cities, play considerable roles in improving the social, cultural, economical and environmental conditions of the urban areas. Such spaces have grabbed more attention in parallel with the growth of an area and the population of the urban regions in various countries; hence, various strategies have been invented and used to locate and distribute them properly throughout the urban environments.

This study has focused the use of integrated multi-criteria AHP with GIS to determine the suitability of the land for parks in the Kota Bharu. The GIS-based AHP as MCE in the land suitability analysis approach can be useful to determine suitable land in urban development. Planning standards of optimal locations are not the only important consideration in the planning process, but also sustainable distances from facilities to people should also be considered. Therefore, this study presented the advantages of integrated GIS-based land suitability analysis and a solution for such complicated decisions. It can also provide an important guidance for future land use changes and cost effective solutions in the cities.

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