SPATIAL MULTI-CRITERIA DECISION ANALYSIS FOR SAFE SCHOOL SITE SELECTION

Zubaidah Bukhari, Ahmad Rodzi Mahmud, Noordin Ahmad

Department of GIS and Geomatic Engineering, Institute of Advanced Technology,
Universiti Putra Malaysia 43400 Serdang, Selangor, Malaysia
Email: *zubaidabukhari@gmail.com*

ABSTRACT

Schools which are located in a strategic and safe area play an important role in improving students' performance and excellence. To ensure both success and long-term sustainability of the school planning, the finding of suitable sites for school is important and challenging. This study delves into a site selection process to establish a systematic public school. It was carried out through the use of geographic information system (GIS) and multi-criteria evaluation model. A set of criteria was used to design a number of potential sites using a spatial analysis model. Mukim Batu which is located in Federal Territory of Kuala Lumpur (WPKL) has been selected as the study area. The final safety model outputs were compared with the field verification data and found to be reliable.

Keywords: site selection; multi-criteria analysis; spatial analysis model

1 Introduction

One of the factors that ensure a good quality in education is a systematic plan developed and well equipped school site. This factor has proven to be an important indicator in students' achievement. However, locating the best school site is always a problem (Church & T.Murray, 2009). There are a lot of processes to be conducted before the suitable school site can be selected. The selection of school site has been normally carried out by many departments involving the district education office (DEO) and the state education department (SED); before submitting it to the ministry level and the economic planner unit to be approved. This multilevel method has some weaknesses such as time consuming, no transparency in the site selection process and the planners have no idea on the location of schools (Aziz, 2004). Planners and decision makers need to consider many factors such as size, access/traffic, utilities, shape, security/safety, costs, locations, noise levels, topography/drainage and soil conditions/plant life (Alaska Department of Education, 1997; Public Schools of North Carolina, 1998). In many cases, the information comes from different agencies which are not properly organized. Although it can be done but considering all of the important criteria and factors in school site selection, it is almost impractical because of time consuming and heavy work load amongst the committee members. Therefore, in some cases these have caused the selected school site for school to fall in areas that have been used for contaminated sites (Muhammad, 2008).

Schools which are located in a strategic area play an important role in improving students' performance and excellence. Generally, every student in Malaysia spends 5 to 8 hours at school (from 7.30 a.m. to 3.30 p.m.) daily. They need to attend academic classes in the morning and co-curriculum activities in the evening. They spend almost half of their age in the school environment since five or six years old (kindergarten level) until 18 years old (when almost all of them complete their secondary level). In order to protect these young generation, schools should be in safe and healthy conditions. Most of these schools are well located. However, there are the existence of several schools which are located in risky areas such as an industry area, main road, highway, floodplain or other hazardous areas that threaten the health and safety of children and school workers.

Today, with the advancement tool in Geographic Information System (GIS) and sophisticated computer technology, a site selection and land suitability become an uncomplicated assignment for planners. Broadly defined, land suitability analysis aims to identify the most appropriate spatial pattern for future site location according to specify requirements and preferences of some activities. The land suitability analysis is an effective method in the planning development based on various specified criteria (Joerin, Theviault, & Musy, 2001). This method is usually used by environment planners and officers in analyzing the interaction between the location, the development and the environmental impact. It permits various factors which cover physical (topography and soil), social (land owner and value of land), and environmental (sensitive areas) to be analyzed and used in helping the decision-making process of the location for an activity (Narimah Samat, 2007). The site suitability analysis has been applied in a wide variety of situations including landfill site selection (Lunkapis, 2004; Siddiqui, Everett, & Vieux, 1996; Wang, Qin, Li, & Chen, 2009), land evaluation for peri-urban agriculture (Thapa & Murayama, 2008), the urban aquaculture development (Hossain, Chowdhury, Das, Sharifuzzaman, & Sultana, 2009), the Japanese scallop aquaculture selection potential site selection (Radiarta, Saitoh, & Miyazono, 2008), public park selection (Zucca, Sharifi, & Fabbri, 2008) and the urban development (Mohit & Ali, 2006).

By using the land suitability approach, M.Fauzi (2005) identified the best area for school siting. She also successfully identified schools near to hazardous areas such as flood and land erosion. Meanwhile, Abdullah (2008) identified two schools which were located very near to the main road. The schools need to be relocated to a better location that is more comfortable and safe for schools children. Aziz (2004) conducted two suitability analysis using the integration of weighted linear combination (WLC), multi criteria evaluation (MCE) and GIS to identified the most critical schools and the most critical regions.

Several studies have focused on school sites issue. However, there are still lacks of research for school site selection modeling that can safeguard school children safety. This study is intended to improve the quality of the school location's decision and solution by integrating the multi-criteria decision analysis and Geographic Information System (GIS) into the decision making process.

2 Materials and methods

2.1 Study area

The Mukim Batu (Figure 1) located in Federal Territory of Kuala Lumpur (WPKL), Malaysia which covers approximately 5300 km^2, with an average elevation of 63 m (207 feet) was choosen as a case study. It has an estimated population of 250,000 million in 2000. Located geographically between $3^0$15'- $3^0$10' North and $101^0$36' - $101^0$41' East, it consists of 49 areas with Sentul covers almost 13% of the area, followed by Jinjang Utara (10%), Segambut Jaya (8%), Jinjang Selatan Tambahan (5.5 %), Kg Palimbayang (5.5%) and Segambut (5%). The other area contributed less than 5% of the study area.

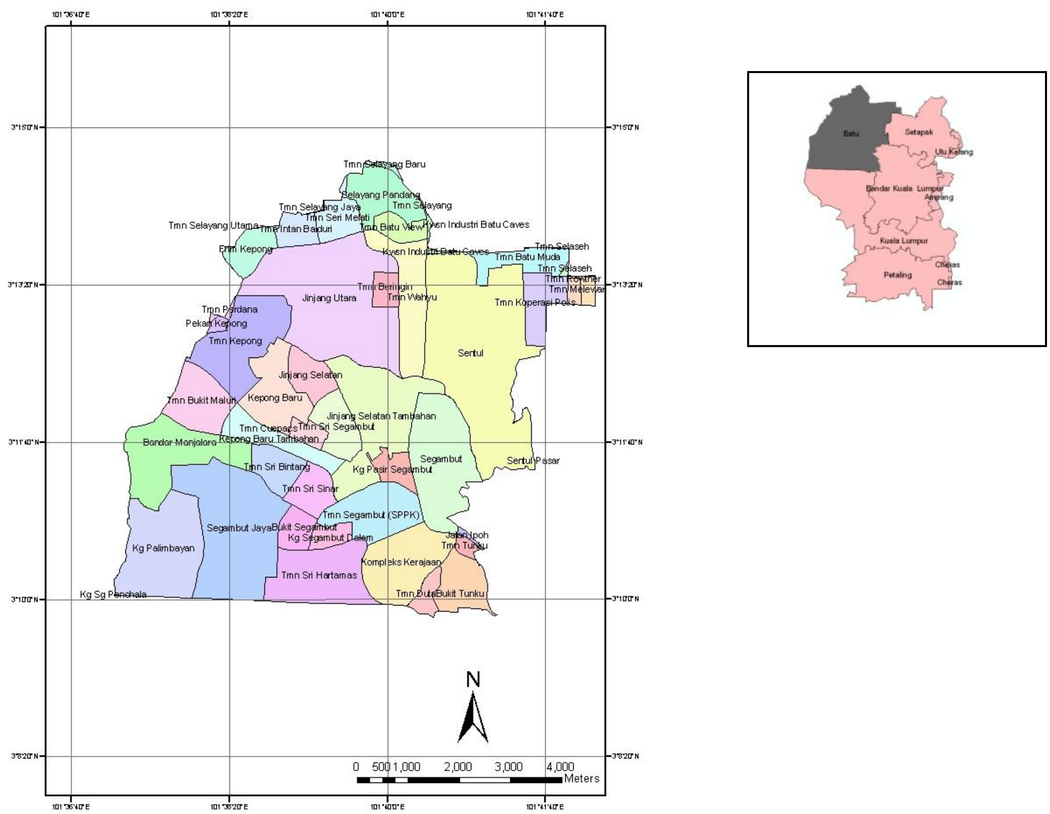

Figure 1: Case Study Area

There are 48 public schools in Mukim Batu, 33 of them are primary schools and the rest are secondary schools. The primary schools consist of 22 national primary schools (SK) and 11 are national aided primary school (SJKC and SJKT). Table 1 shows the number of schools in the study area. This study focuses on primary schools only.

The table shows that 25 primary schools are operated in the morning session, while 3 of them are operated in the afternoon schools. Meanwhile, four of the primary schools shared their school buildings with other schools.

Table 1 : Number of schools in the study area

Type of Schools	Number of Schools	Number of schools in single session		Number of schools in double session	Building status		Enrolment	Number of Classroom
		Morning	Afternoon		Own Building	Share with other building		
SK	22	17	2	3	20	2	13467	551
SJKC	9	6	1	2	7	2	13603	286
SJKT	2	2			2		602	20
SMK	15	5		10	15		24674	504
TOTAL	48	30	3	15	44	4	52346	1361

Source : EPRD (2009)

2.2 Software and hardware used

GIS software used in this study were ArcGIS 9.2 (The Environment System Research Institute), MapInfo Professional 8.5 SCP, ArcView GIS 3.3 and Geographic Calculator 6.0. Data processing and modeling were performed mainly with ArcGIS 9.2 while MapInfo Professional 8.5 SCP, ArcView and Geographic Calculator was used for standardizing the input format. ArcGIS 9.2 was operated on a AMD Turion^{TM} 64X2 Dual-Core laptop with a 2 GB of RAM, 160 GB harddisk.

2.3 Identification of criteria and data collection

This research starts from reviewing, investigation and comparison of guidelines used by other countries to find a complete and reliable list of criteria for school site selection focusing on safe location. Analytic Hierarchy Process (AHP) as a multi-criteria decision analysis (MCDA) technique was used to organize the identified criteria into a hierarchy structure before obtaining a judgment expertise in weighting land suitability factors. Studies continue with the development of analysis model to perform the spatial operation. Figure 2 shows the conceptual framework of the study.

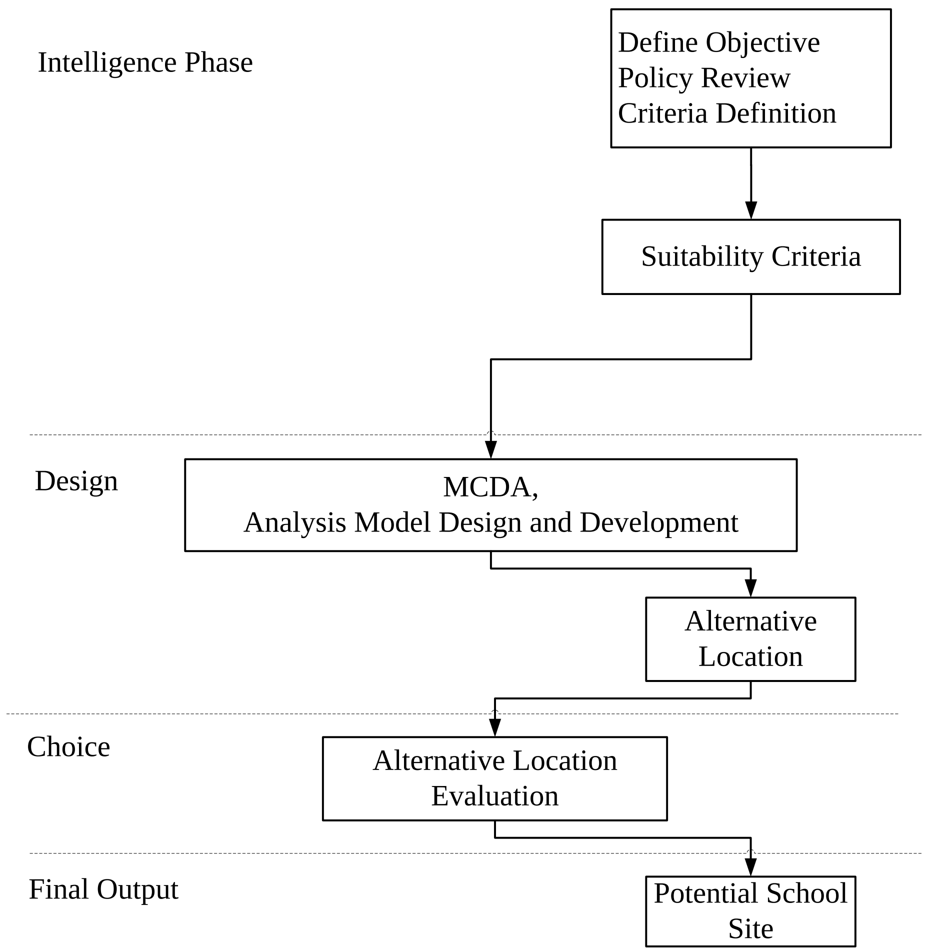

Figure 2: Conceptual Framework of the study

2.4 School siting phase

2.4.1 Intelligence Phase

The intelligence phase has led to the definition and specification of the school. The aim of this study is to determine the school location in a safe and healthy environment. The Investigation and comparisons between selected states guideline has been conducted to identify parameters for suitable school siting. Ten parameters have been identified for this purpose. They are the distance from industry areas, the distance from commercial areas, the distance from the main road, air pollution index (API) reading, noise level reading, land slope, height, flood prone, distance from stream and the distance from an electrical transmission line.

The range of score chosen varies in all criteria. The number of class and the interval of class are designed to distinguish the quality of the sites proportionally for the corresponding criteria. The subsequent section will define the criteria specifically and Table 2 defines the criterion score for each parameters.

- *Distance from industry area*

Schools must be located away from industrial areas because of the safety risk caused by the heavy traffic of the route. There is also the possibility of noise and air pollution depending on the nature of industry in the area. Georgia Department of Education (2003) and California Department Of Education (2004) states school site should not be located in areas zone for commercial or industrial development. Risk/hazard analysis should be done if proposed development area is within 3 mile (5 km) radius from the heavy industry. The industry area for this study is categorized as the medium and light industry (Kuala Lumpur City Hall, DBKL). Based on the previous studies, the distance from the industry area to schools were suggested at least 500 m. (Abdullah, 2008; Aziz, 2004). For this study, the acceptable distance from industry area to school site was at least 1 km. The industry area was obtained from DBKL.

- *Distance from commercial area*

Schools should be located far from the commercial area because of the heavy traffic that contributes to air and noise pollution. This is also to avoid school children to waste their time playing in the arcade section. For this study, the acceptable distance from the commercial area to schools was at least 1 km. The commercial area was obtained from DBKL.

- *Proximity to main road*

Transportation on roads produces polluted substances which have negative effects for human health (Salvesen, Zambito, Hamstead, & Wilson, 2008). Several studies have found that living or studying in schools near major roads raising risk of heart and lung problems but the risk declined markedly after 150 m (Green, Smorodinsky, Kim, McLaughlin, & Ostro, 2004). Buffer size from 150 m to 450 m was assigned to the study area. Major roads for this study are defined as those primary roads that are classified as highway and main road. Roads under street categories were omitted, as these tend to be smaller, two-lane roads with relatively low traffic volumes. The data on major roads were obtained from DBKL

- *API reading*

API is used for measuring air quality. The Department of Environment Malaysia (DOE) is responsible to monitor ambient air quality throughout Malaysia. Malaysia has 51 locations to detect any significant change in the air quality. These monitoring stations are strategically located in residential areas, schools, industrial areas and areas with high traffic volume (Department of Environment Malaysia, 2007). The API reading for this study was obtained from seven air quality monitoring stations which cover approximately the area of Mukim Batu, Kuala Lumpur namely; Country Heights, Kajang, Pelabuhan Klang, Selangor, Petaling Jaya, Selangor, Shah Alam, Selangor, SMK Seri Permaisuri, Cheras and SK Batu Muda, Batu Muda.The records for the API reading were obtained since January 2009 to April 2009 daily. The records of most frequently API reading had been used to represent the overall air quality for selected API stations. The air quality readings are based on DOE classification.

- *Noise level reading*

Activities such as industrial, development projects and traffic generate excessive noise. Noise pollution has an impact on health and reduces productivity (Department of Environment Malaysia, 2007). School is categorized under Noise Sensitive Area. Noise compliances were based on the limits recommended in the 'Planning Guideline for Environmental: Noise Limits and Controls'. In 2007, noise levels at several areas with a high traffic volume in Kuala Lumpur were measured. The levels ranged from 59.3 to 62.7 dBA . Meanwhile, noise levels for several industrial areas were ranged from 49.3 to 57.5 dBA. According to DOE, in day time, noise level for school should be from 0 to 50 dBA and at night, noise level should be from 0 to 40 dBA (Department of Environment, 2004). Unfortunately, the noise level for Mukim Batu, Kuala Lumpur is not available. Surrogate data were used for representing the noise level reading in the study area that is ranged from 49.3 to 62.7 dBA. For this study, the API stations as stated previously would be used as a surrogate station.

- *Land slope*

Several studies have found that 45% on the slope failures occurred in the gentle slope region (5^0-15^0), 35% of them occurred in moderate slope regions (15^0 - 35^0) (Yong, Mukherjee, & Youn, 2008). It is recommended that for the development on the areas where slope angles generally exceed 10^0, a proposed development should be subjected to a geotechnical investigation of surface (Ryde). Based on the Ministry of Education (MOE) and Department of Town and Country Planning (JPBD) guidelines, schools should not be built on the slope that more than 10^0. Buffer size from 10 to 20 was assigned to the study area. The data on slope were obtained from Department of Survey and Mapping, Malaysia (JUPEM).

- *Height*

Based on the MOE and JPBD guideline, schools should not be built on the area that is more than 60 meter height. The data on height was obtained from JUPEM.

- *Flood prone*

Schools should be located outside a flood zone due to the possible for personal injury, loss of life and major property damages. A 100-year floodplains data are the most suitable data for school safety analysis (Georgia Department of Education, 2003). Since there was no available data for 100-year floodplains of the study area, the analysis was limited to those areas for the year 2000, 2001 and 2003 floodplains. The 3-year floodplains have been obtained from Malaysian Geospatial Data Infrastructure (MyGDI).

- *Distance from stream*

Schools should be located far from streams to ensure schools are safe from natural disaster such as flash flood, mud flood and erosion problems which stem from their closeness to river. Indiana State Board of Education (2002) clearly states no school can be built within 500 feet (152.4 meter) of a stream. For this study, the acceptable distance from the school site to the nearest stream was at least 300 m. The data on stream was obtained from JUPEM.

- *Distance from electrical transmission line*

Schools should be located far from electrical transmission line to ensure students and schools staffs are protected from the high voltage electrical effect (quote from previous study). The buffer size of 150 m has been used based on California Department of Education guideline (California Department Of Education, 2004). The data on electrical transmission line was obtained from Public Works Department of Malaysia (JKR).

Table 2: Site Suitability Evaluation Criteria

Proximity to industry area	Score	Classification
0 - 500 m	1	Not suitable
500 – 1000 m	2	Less suitable
1000 – 1500 m	3	Suitable
> 1500 m	4	Most suitable
Distance from commercial area		
0 -500 m	1	Not suitable
500 – 1000 m	2	Less suitable
1000 – 1500 m	3	Suitable
> 1500 m	4	Most suitable
Proximity to main road		
0 - 150 m	1	Not suitable
150 – 300 m	2	Less suitable
300 – 450 m	3	Suitable
> 450 m	4	Most suitable
API reading		
0 – 50	5	Good
51 – 100	4	Moderate
101 – 200	3	Unhealthy
201 – 300	2	Very Unhealthy
> 301	1	Hazardous
Sound Level (Day Time)		
0 - 50 dBA	5	Good
51 - 55 dBA	4	Moderate
56 - 60 dBA	3	Unhealthy
61 - 65 dBA	2	Very Unhealthy
> 65 dBA	1	Hazardous
Slope (degree)		
0 - 10	3	Suitable
10 - 20	2	Less Suitable
> 20	1	Not Suitable
Height (meter)		
< 30	3	Most suitable
30 - 60	2	Suitable
> 60	1	Not suitable
Proximity to Flood prone		
0 - 500 m	1	Not Suitable
500 - 1000 m	2	Less suitable
1000 - 1500 m	3	Suitable
> 1500 m	4	Most Suitable
Distance from stream		
0 - 150 m	1	Not suitable
150 - 300 m	2	Less suitable
300 - 450 m	3	Suitable
> 450 m	4	Most suitable
Proximity to electrical transmission line		
0 - 150 m	1	Not suitable
150 - 300 m	2	Less suitable
300 - 450 m	3	Suitable
> 450 m	4	Most suitable

2.4.2 Design Phase

The design phase has led to the identification of a few potential sites based on the specified criteria. This was obtained by three steps: first, the expert's knowledge has been used for giving the evaluation score for the defined criteria; a suitability map was generated. Finally using the model builder in ArcView Spatial Analyst, a set of potential school location was generated.

- *Using AHP to evaluate the defined criteria*

The model structure for identifying suitable sites for safe school was built based on hierarchical structures (Figure 3). There are ten criteria to meet the school safety objective. To apply all the criteria in decision making process, Analytic Hierarchy Process (AHP) method was used. AHP which was developed by Thomas L. Saaty in the 1970s is a process for ranking alternatives. A numerical score need to be developed to rank each alternatives based on how good each alternative suits the decision maker's criterion. The relative importance for each criterion was set by pairwise comparison using a range from 1 (equally important) through 9 (extremely important). Reciprocal values mean reverse level of importance for example 1/9 is identified as extremely non important.

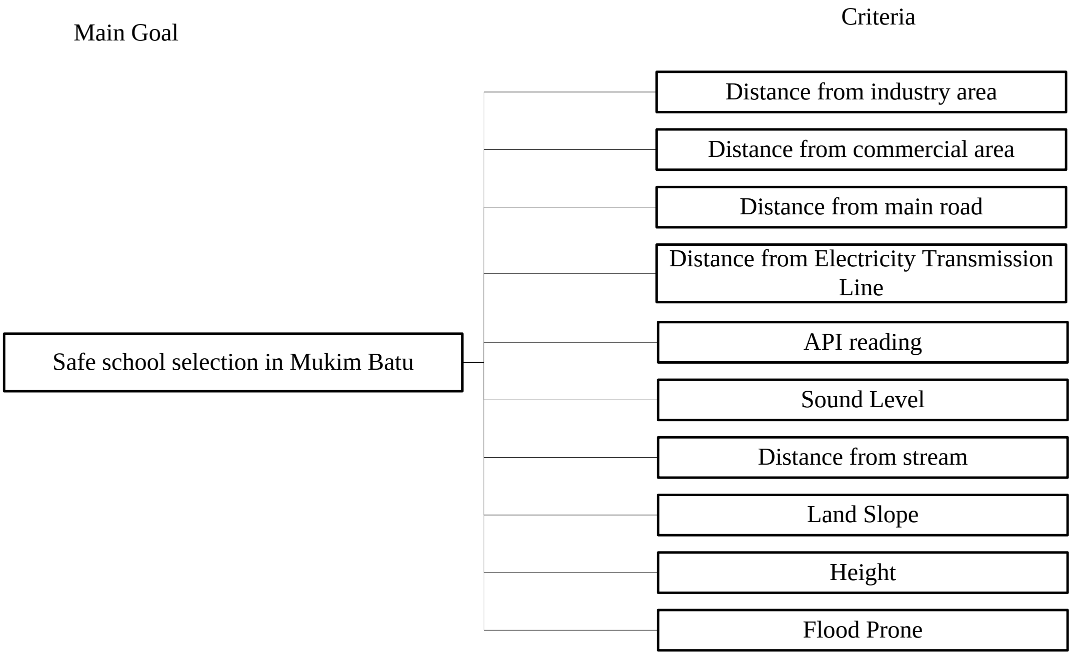

Figure 3: A hierarchical modeling scheme to identify suitable site for primary school location in Mukim Batu

In this study, the identified criteria need to be rank in order to decide the best site for school siting. Pairwise comparison was performed using Web-HIPRE, a Java based multi-criteria decision support engine developed in System Analysis Laboratory at Helsinki University of Technology (Web-HIPRE, 2007). Figure 4 shows the comparison table for school safety analysis criteria.

Figure 4: Pairwise comparison matrix for school safety analysis criteria

For each criterion, scores are set out through discussions and interviewed with a group of expertise. The result of this method is shown in Table 3.

Table 3: Weightage for school safety analysis criteria

Criteria	**Weight (%)**
Land Slope	22.40%
Height	22.00%
Distance from Industry area	20.60%
Distance from Electrical Transmission Line	12.30%
Air Pollution Reading (API)	7.10%
Sound Level (Day Time)	4.40%
Distance from Main road	4.20%
Flood Prone	2.60%
Distance from Commercial area	2.30%
Distance from stream	2.10%
	100.00%

2.4.3 Development of Suitability Map

The suitability map can be divided into constraint and factors. A constraint is a criterion that determines which areas should be excluded from or included in the suitability analysis. In this study the constraint were the reserve areas for electricity, transportation, stream, park areas and land more than 60 m height. A factor is a criterion that contributes to a certain degree to the suitability. In this study, the ten criteria which were mentioned from the previous section will be used as the factors. All the criteria and constraint has been input as GIS file in the personal geodatabase.

2.4.4 School Safety Suitability Model

In this study, ModelBuilder for ArcView/Spatial Analyst has been used for school suitability model, which is well known as flowchart approach (Malczewski, 2004). In the flowchart approach a school safety suitability model is constructed of individual processes from input data, basic GIS operations, and derived data which are then linked together. The creation of the model takes place in a user friendly GUI with the help of drag-and-drop capabilities. Using weighted linear combination (WLC), all the criterion score (x_{ij}) for *m* factors will be added and multiplied with the relative important weight (w_m) which was obtained from the expert score value in locating the suitable site for the new school, S_{ij} using following formula:

$$S_{ij} = \sum_{m=1}^{M} x_{ij}.w_m.c_m$$

where

S_{ij} = suitability score of *i,j* location
x_{ij} = criterion score for *m* factor of i,j location
w_m = weightage of relative importance for *m* factor
c_m = boolean value of constraint factor of *i,j* location
m = consideration criterion or factors

This process was done by giving the weight to all the inputs and percentage of influence of each input. The higher percentage is a more influence of a particular input will exist in the suitability model.

2.4.5 Choice Phase

- *Definition of new criteria*

The last phase of this study is the evaluation and choice of alternative options. The potential sites for the schools were evaluated using different set of criteria. For this last phase, the area of schools building has been considered. According to JPBD (1997) guideline, suitable area for primary school should be more than 2.4 hectare. The area with less than 2.4 hectare has been omitted.

- *Evaluation Model*

Model verification is important for data quality control and for testing the model. Comparison between the model suitable safety sites with the proposed school location provided by DBKL was carried out. The proposed school location was obtained from DBKL in digital softcopy and was digitized for further analysis. The both sites location were overlaid to determine how much the proposed school location matched with the model output.

3 Results and Discussion

This study focused in safe school site selection. The potential sites should have appropriate safety criteria in order to provide schools children and staff in safety and healthy environment. Ten parameters contributed to safe location were identified (see Table 12). The suitable area provided by JPBD for school building has also been used for optimum selection. In this study, approximately 168 hectare of the potential area (8%) was identified as score 5 (most-suitable), and this area was located on the North, East and South of the region (Figure 5). There was 46% of the potential area identified as suitable location (score 3 and 4) and 22% for less suitable location (1 and 2). The areas of more than 60 meter height contribute 24% of the potential site. (score 0)

Verification was done by comparing the location of suggestion school location and suitable sites obtained from the models. There were 7 locations that match with the suitable sites model. It contributes 37% of overall suitable site location (score 3 and 4). There were two areas of DBKL proposed sites that fell in the constraint areas. The other ten areas have less than 2.4 hectare. This contributes for unmatched site selection between the both outputs (Figure 6)

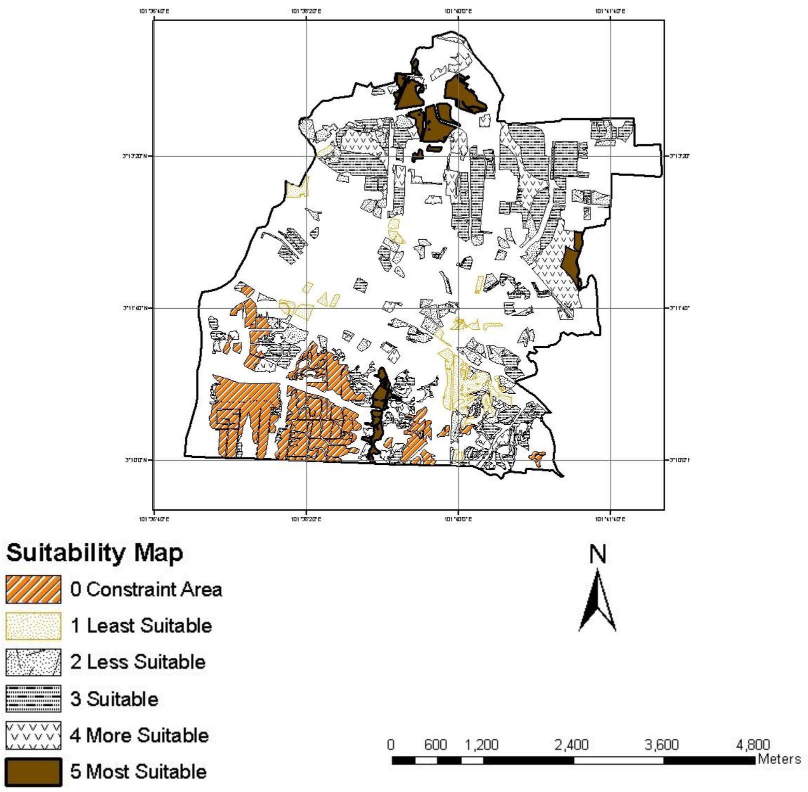

Figure 5 : Suitability Map from Model Output

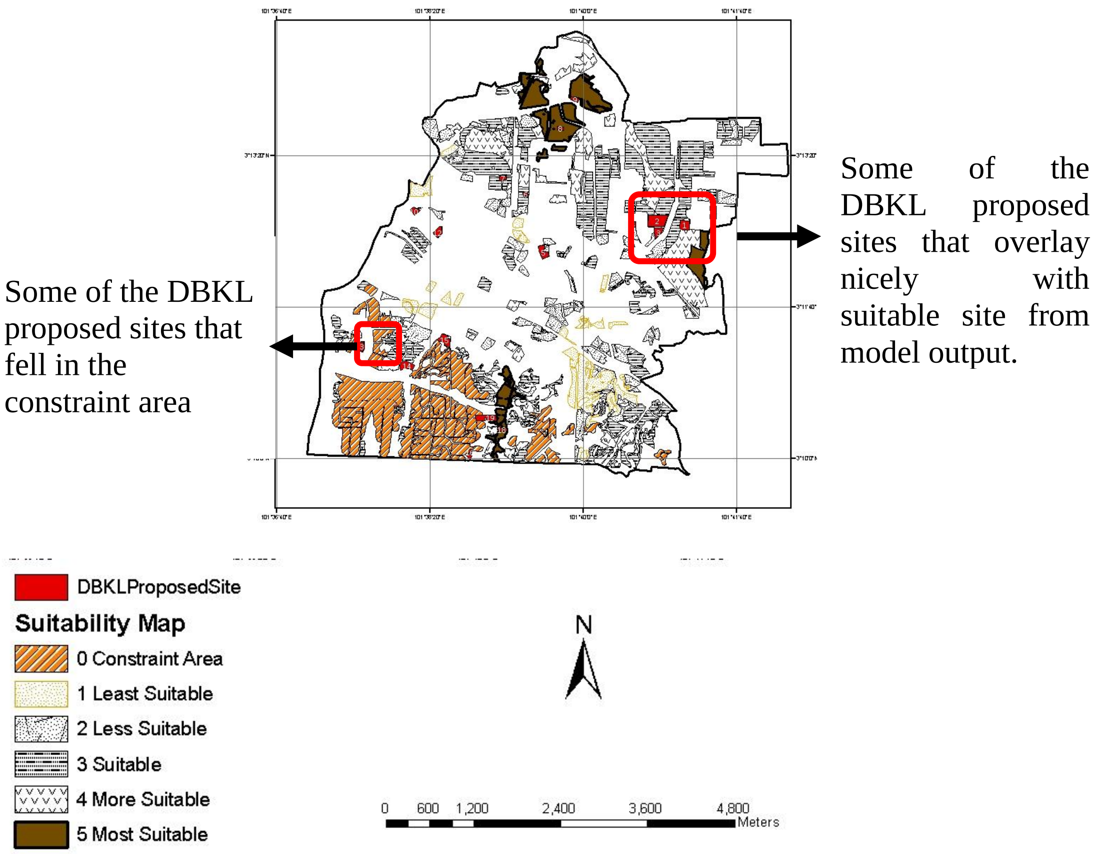

Figure 6: The suitability map intersects with DBKL proposed site

4 Conclusion

The methodology that was developed and applied in this study has combined multi-criteria evaluation technique with GIS in supporting a school site selection problem. In this study a framework is provided to effectively design and evaluate alternative sites for safety primary school location. For this kind of objective, a specific methodology or a set of specific criteria to select the areas did not exist in the school site selection guidelines provided by Department of Town and Country Planning (JPBD) of Malaysia. The selection was mainly based on expert's knowledge and strongly influenced by the existing of the City Master Plans. The methodology applied allows enhancing the role of this type of schools as an opportunity for a more sustainable school planning. The main advantages of the methodology used in this study are the efficient combination of multi-criteria evaluation with spatial data analysis tools that support a better school site planning and provide a logical and scientific foundation into which the values of decision makers and stakeholders can be integrated.

References

Abdullah, N. (2008). *Gis as a Tools to Identify Land Suitability for Primary School Relocation.* Faculty of Engineering, Universiti Putra Malaysia.

Alaska Department of Education. (1997). Site Selection Criteria and Evaluation Handbook. Retrieved 20 January 2009 from http://www.eed.state.ak.us/Facilities/publications/SiteSelection.pdf

Aziz, A. (2004). *Spatial Decision Support System For School Siting.* Faculty of Engineering, Universiti Putra Malaysia.

Bahagian Perancangan dan Penyelidikan Dasar Pendidikan. (2009). *Risalah Maklumat Asas Pendidikan*

California Department Of Education. (2004). School Site Selection and Approval Guide. Retrieved 20 January 2009 from http://www.cde.ca.gov/ls/fa/sf/schoolsiteguide.asp

California Department Of Education. (2004). School Site Selection and Approval Guide. Retrieved 13 November 2008, from http://www.cde.ca.gov/ls/fa/sf/schoolsiteguide.asp

Church, R. L., & T.Murray, A. (2009). *Business Site Selection, Location Analysis, and GIS*.

Department of Environment. (2004). *The Planning Guidelines for Environmental Noise Limits and Control*.

Department of Environment Malaysia. (2007). *Annual Report Department of Enironmental 2007*. (Ministry of National Resource and Environmental Malaysia).

Department Of Town and Country Planning Peninsular Malaysia. (1997). *Planning Guidelines JPBD 19/97*, .

Georgia Department of Education, F. S. U. (2003). *A Guide to School Site Selection*.

Green, R. S., Smorodinsky, S., Kim, J. J., McLaughlin, R., & Ostro, B. (2004). Proximity of California Public Schools to Busy Roads. *Environmental Health Perspectives, 112*(1), 61-66.

Hossain, M. S., Chowdhury, S. R., Das, N. G., Sharifuzzaman, S. M., & Sultana, A. (2009). Integration of GIS and multicriteria decision analysis for urban aquaculture development in Bangladesh. *Landscape and Urban Planning, 90*(3-4), 119-133.

Indiana State Board of Education. (2002). School Facility Guidelines from http://www.doe.state.in.us/stateboard/constguide.html

Joerin, F., Theviault, M., & Musy, A. (2001). Using GIS and outranking multicriteria analysis for land-use suitability assessment. *International Journal of Geographical Information Science, 15*(2), 153 - 174.

Lunkapis, G. J. (2004). *GIS as Decision Support Tool for Landfills Siting*. Paper presented at the MAP Asia Conference 2004.

M.Fauzi, I. F. (2005). *Analisis Perletakan Kemudahan Pendidikan Menggunakan Sistem Maklumat Geografi (GIS).* Universiti Teknologi Malaysia.

Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning, 62*(1), 3-65.

Mohit, M. A., & Ali, M. M. (2006). Integrating GIS and AHP for Land Suitability Analysis of Urban Development in a Secondary City of Bangladesh. *Jurnal Alam Bina, Jilid 8, No. 1*.

Muhammad, M. J. (2008). *EduGIS.KL Dalam Pengurusan JPWP Kuala Lumpur.* Paper presented at the Seminar Kebangsaan Pengurusan Maklumat Pendidikan EMIS ke-IX, Bagan Lalang, Selangor.

Narimah Samat, T. M. (Ed.). (2007). *Sistem Maklumat Geografi Dalam Analisis Guna Tanah*: Universiti Sains Malaysia.

Public Schools of North Carolina. (1998). Land for Learning. Retreived 20 January 2009 from http://www.schoolclearinghouse.org/pubs/schsite.pdf

Radiarta, I. N., Saitoh, S.-I., & Miyazono, A. (2008). GIS-based multi-criteria evaluation models for identifying suitable sites for Japanese scallop (Mizuhopecten yessoensis) aquaculture in Funka Bay, southwestern Hokkaido, Japan. *Aquaculture, 284*(1-4), 127-135.

City of Ryde, Slope Instability Risk Zones retrieved on Disember 2009 from http://www.ryde.nsw,gov.au/WEB/SITE/RESOURCES/DOCUMENTS/Planning/ slopeinsatabriskzone.pdf

Salvesen, D., Zambito, P., Hamstead, Z., & Wilson, B. (2008). Safe Schools: Identifying Environmental Threats to Children Attending Public Schools in North Carolina. Retrieved 10 Disember 2009 from http://www.ie.unc.edu

Siddiqui, M. Z., Everett, J. W., & Vieux, B. E. (1996). Landfill siting using geographic information systems: A demonstration. *Journal of Environmental Engineering, 122*(6), 515-523.

Thapa, R. B., & Murayama, Y. (2008). Land evaluation for peri-urban agriculture using analytical hierarchical process and geographic information system techniques: A case study of Hanoi. *Land Use Policy, 25*(2), 225-239.

Wang, G., Qin, L., Li, G., & Chen, L. (2009). Landfill site selection using spatial information technologies and AHP: A case study in Beijing, China. *Journal of Environmental Management, 90*(8), 2414-2421.

Yong, N. S., Mukherjee, A., & Youn, F. K. (2008). Using Geospatial Model For Managing Risk of Slope Failure in Singapore [Electronic Version]. Retrieved January 8, 2010, from http://www.esrisingapore.com.sg

Zucca, A., Sharifi, A. M., & Fabbri, A. G. (2008). Application of spatial multi-criteria analysis to site selection for a local park: A case study in the Bergamo Province, Italy. *Journal of Environmental Management, 88*(4), 752-769.