© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie
ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

GIS and Multi-criteria Analysis for School Site Selection (Study Case: Malacca Historical City)

A. A. Mustaffa[1*], B. Bahiah[1], A. W. Rasib[2], M. B. Saifullizan[1]

[1]Centre of Applied Geomatics for Disaster Prevention, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA

[2]Tropical Map Research Group, Faculty Geoinformation and Real Estate, Universiti Teknologi Malaysia, 81310 Skudai, Johor, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2021.13.04.022
Received 19 October 2020; Accepted 14 March 2021; Available online 30 April 2021

Abstract: School sites selection is an essential process which needs information on various fields. The process includes scientific justification, judgment and a finding of suitable land, which consider financial, social, ecological and political perspectives, that limit conflicts and supports agreement among the decision makers. A set of school suitability map would be very useful for education planners when making a complex decision within a short period of time. This study will utilize both spatial and non-spatial parameters to establish a systematic site selection process for primary schools in Melaka Tengah District. It was carried out by using Geographic Information System (GIS) and Multi-criteria Decision Analysis (MCDA). Three analysis namely demographic, safety and constrain analysis were used to identify the potential sites. Then accessibility analysis, using expertise and public opinion were used to further analyze the potential site. The resulted map showed 54.% of the total area is highly not suitable, leaving 46% suitable for school sitting. The final safety model output was compared with field verification data from State Education Department (JPN Melaka) and Malacca Historical City Council (MBMBB).

Keywords: Site selection, multi-criteria analysis, GIS

1. Introduction

Appropriate site determination for a building of a new school is a signifigant long-haul investment and an essential decision that could generally impact the advantage loss of the available resources [1]. A safe school that supports high-quality education and promotes sustainable and healthy communities is closely related to the school location. School which are located in a strategic area play a significant function in improving student's presentation and greatness. In most cases, every student in Malaysia goes through 5 to 8 hours at school (from 7.30 a.m to 3.30 p.m) daily. They have to go to attend scholastic classes toward the beginning of the day and co-curriculum activities in the evening. They spend half of their age in the school environment sice 5 or 6 years old until 18 years old when they complete their secondary level [2]. So as to protect these young generation, schools ought to be in safe and healthy conditions.

Being one of the most fast-developing nations, Malaysia placed a high priority on education, especially building the adequate school. In Malaysia Budget 2019, in the section of improvement and maintenance of schools, RM652m was allocated for the upgrading of schools and RM100m for the re-construction of dilapidated schools through Public-Private-Partnership (PPP) projects [3]. Many criteria and conflicting characteristic is involved in evaluating the school locations [4], [5]. As such, the planning process as it is practice now is time consuming as well as confusing because

*Corresponding author: mustafa@uthm.edu.my

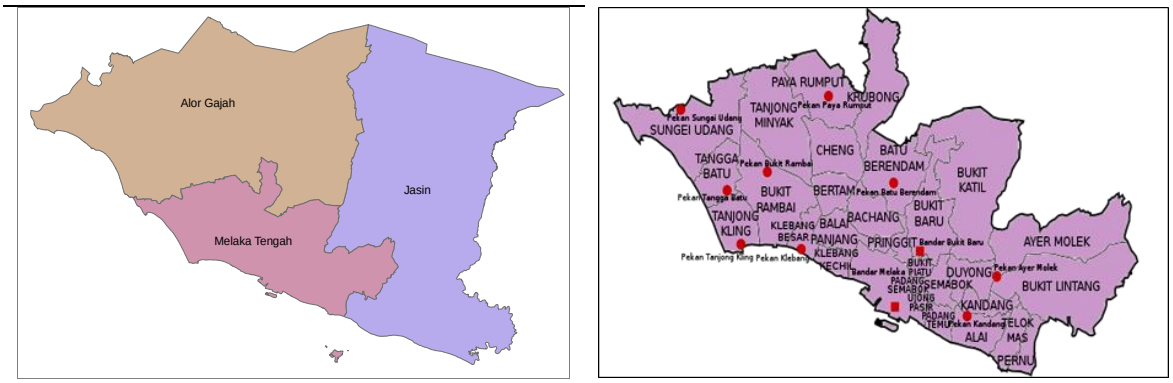
too much information has to be cramped within a certain timeframe [6]. The main problems are that the planners at the ministry level have no mechanism to access all the basic data instantly [7].

In year 2001, Malaysian development planning system was refined in line with the Town and Country Planning Act, 1976 (Act 172). The amended Act plays a major role in the reform of the development planning system in the sense that it insists the incorporation of the GIS into the development plan preparation process [8]. These days, the use of Multi-criteria Decision analysis (MCDA) incorporated with GIS approach become ideal and serves for the decision makers and land planners in education areas [9]. The method enables to handle massive geospatial issues related to land use suitability, site selection and resource evaluation isssues. Generally, it can provide immeasurable opportunities for land use planning and management problem [10]. MCDA allow to consider both qualitative and quantitative basis that assis the decision maker's judgment to be specific and to choose optimal choice based on a scientific technique. The technique assesses the accessible alternatives on various attributes that have a distinctive character and evaluation units to maximise the benefits [11].

Thus this study is done to effectively identify a suitable location for primary school sitting by using GIS and MCDA. It begins with getting information on policies and factors that influence planning. These factors were broken into parameters which then formulated into the weightage system to indicate the effectiveness of present educational planning. From the result, planning model will be planned and develop, so that the location of new schools and redistribution of students can be determined [12].

2. Study Area

The case study is focused on District of Melaka Tengah (Fig. 1) which located geographically at 2º 19' 35.3454 North and 102º 20' 44.5734" East. Malacca is the third smallest state in Malaysia. It is located in the southern region of the Peninsula Malaysia, next to the Straits of Malacca. This historical city center has been listed as a UNESCO World Heritage Site since 7thJuly2008 [9]. The state of Malacca covers an area of 1,664 km^2. It is divided into 3 districts and 4 local authorities [13], [14].



(a) (b)

Fig. 1 - (a) Counties in Melaka Tengah; (b) District In Malacca State

There are 130 schools in the study area which consist 92 primary and 38 secondary schools. Table 1 shows the fractions of schools in Melaka Tengah district according to the type of school. Out of 130 schools, 3 schools operate at double-session while the rest are single-session [15]. When schools function at double session, it means that the student population far exceeds the capacity of the available classroom.

Table 1 - Types of School (EMIS Database, JPN Melaka)

Type	Number
Sekolah Kebangsaan	57
Sekolah Jenis Kebangsaan (Tamil)	3
Sekolah Jenis Kebangsaan (Cina)	29
Sekolah Rendah Arab	3
Sekolah Menengah Agama	1
Sekolah Menengah Kebangsaan	32
Sekolah Menengah Vokasional	1
Sekolah Menengah Berasrama Penuh	1
Sekolah Menengah Kebangsaan Agama	2
Sekolah Menengah Teknik	1

3. Materials and Method

3.1 Software and Hardware Used

GIS software used in this study were Arc GIS 10.3, and Map Info Professional. The GIS is the most widely and reliably used decision making tool for the spatially related matters in the modern world. The role of GIS technology can handle spatial data to allocating an economical and safe place for the selection process. ArcGIS is a GIS software delivered by Esri. It is one of the most commonly used GIS programs both by companies and in education. It was initially released in 1999 and has developed ever since. While, MapInfo Professional is a desktop GIS software product provided by Pitney Bowes. MapInfo Pro allows users to visualize, analyze, edit, interpret, understand and output data to reveal relationships, patterns, and trends. MapInfo Pro allows to explore spatial data within a dataset, symbolize features, and create maps [16]. Data processing and modelling were performed maily with the ArcGIS 10.3, while MapInfo Professsional was used for stardardizing the input format.

3.2 Identification of Criteria and Data Collection

This study starts from reviewing, investigating and comparison of guidelines used by other countries and Malaysian researchers to find a complete and reliable list of criteria for school site selection focusing on safe location [17]. The whole process in site selection will incorporate Hierarchy Process (AHP) as a multi-criteria decision analysis (MCDA) technique which was used to organize the identified criteria into a hierarchy structure before obtaining judgment expertise in weighting land suitability factors (Fig. 2). This study was guided by the value-focuses approach framework (Table 2) which has been modified from [18], [19].

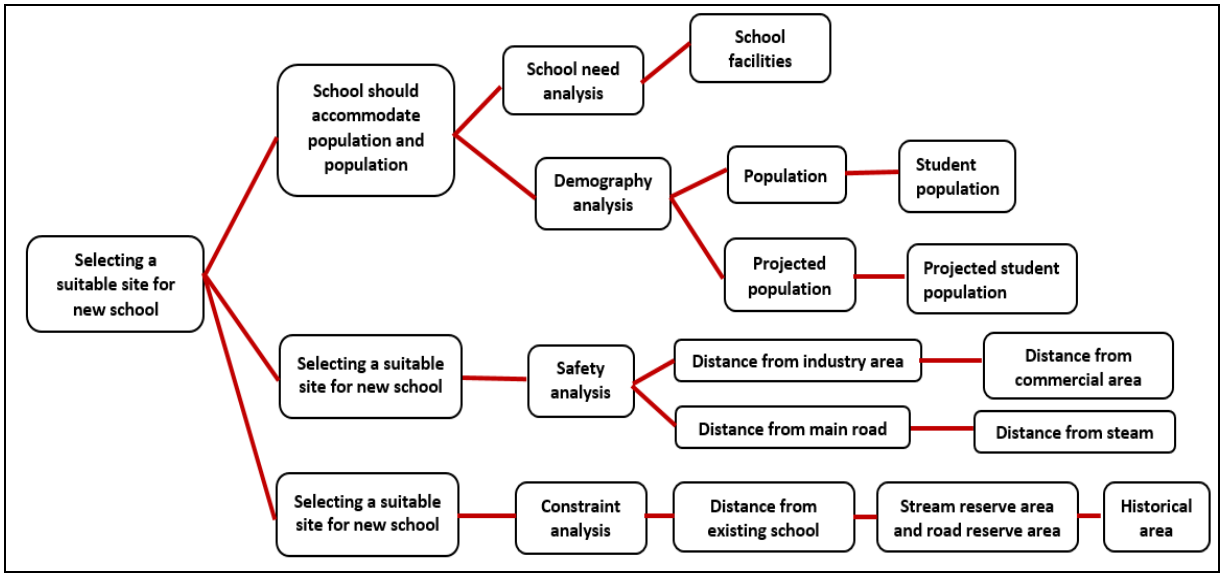


Fig. 2 - Criteria tree for suitability mapping and hierarchical structure

Table 2 - Sequence of activities performed in the study

Phase	Activities
Intelligence	a. Conceptual framework including • Main objective and sub-objectives identification • Criteria definition that can be used to satisfied each sub-objective • Constraints definition of areas unsuitable for the school site. b. Database design • Conceptual • Logical • Physical c. Database development • Data collection • Data editing • Topology development • Data format interchange • Build Geodatabase

Design	d. Design proper location for the school by: • Performing a spatial multi criteria evaluation to produce a suitability map
Choice	e. Evaluation and ranking of the designed alternatives • Performing spatial multi criteria evaluation. • Identification of the most appropriate area for new schools.

3.3 Intelligence Phase

The intelligence phase will define and give specification of the school, linked directly to the aim of this study, which is to determine the school location in a safe and healthy environment. The first analysis to be done is school need analysis which will determine the ideal number of the schools needed in the area. It can be calculate by using guidelines from Federal Department of Town and Country Planning (PLAN-Malaysia) [20] and Eqn. (1). This study were using the population approach which is based on the number of residents in neigborhoods.

$$S = \frac{P}{n} \tag{1}$$

where: S = ideal number of school, P = population, and n = maximum number of residents according to the guidelines.

Based on current estimates, the number of primary schools is more than sufficient, compared to high school that requires 20 new schools (Table 3). The county which requires a relatively high number of schools is Mukim Bachang, Mukim Batu Berendam and Mukim Tanjung Minyak. This may be due to the increasing number of residents in Melaka Tengah district by 30.6%. All three of the county is experiencing rapid development compared to the other district [21]. A detail research is required to determine the exact number of new schools needed for each county based on the total of classroom available.

Table 3 - Calculation using PLAN-Malaysia Guidelines

School	JPBD Resident Guideline	Max. Num. of Residents	Population	Num. of School
		n	***P***	***S***
Primary	3000 -7500	7500	522202	70
Secondary	> 9000	9000	522202	58

Suitability analysis is carried out to further analyze the location of potential site. Through the analysis, the area with suitability criteria is identified. Further on, it can determine the number of school that fell within classified zone (1-Not Suitable; 2-Marginally Suitable; 3-Moderately Suitable; 4-Highly Suitable). The suitability analysis consists of Demography Analysis and Safety Analysis.

Demography Analysis will determine a suitable location that can accommodate the enrolment and population growth. Four parameters have been identified for this purpose they are population, projected population, students and projected students [22]. In Safety Analysis, five parameters based on the PLAN-Malaysia guidelines, education guidelines, literature and other selected country education guidelines have been identified for this purpose. They are distance from industry area, distance from commercial area, and proximity to main road, flood prone, and distance from stream. It is necessary to define the constraints for school building. Constraint is a criterion that determines which areas should be excluded from or included in suitability analysis. The constraint factor in this study are: (i) school should be built near to historical site, (ii) Schools should not be built 1 to 1.6 km from existing school, and (iii) schools should not be built near swamp or lake.

3.4 Design Phase

This phase will identified of a few sites based on the specific criteria obtained from evaluation scores by expert's knowledge. The database development includes the spatial data collection and data input, data editing, topology development and data format change. During this study there are 130 public schools exist in the study area. Table 4 shows the data attribute from EMIS Portal and Melaka State Education Department. The spatial data includes information on schools, enrollment, teachers and staff. Table 5 shows the data type and sources for spatial data from Malacca Historical City Council, Malaysia Geoportal and PLAN-Malaysia.

Multi criteria evaluation (MCE) is applied in the design phase of this study in order to allocate weight to the main factor in demography analysis, safety analysis and constrain analysis. One of the MCE that involve in this phase is Pairwise comparison Method (Fig. 3). This method involves the comparison between criteria and factors. This method can convert verbal judgments of relative importance into a linear set of weights. It was develop by [23] in the context of

a decision making process known as the Analytical Hierarchy Process (AHP). The AHP technique was mainly employed to allocate weights to identify criteria and factors for suitability areas [24] (Table 5).

Table 4 - Attribute data requirement

Data Type	Detail
Schools Information	The data includes information on schools, enrollment, teachers and staff

Table 5 - Spatial data requirement

Data Type	Detail
Transport Network Plan	Local Authority Road Network In Melaka Tengah District.(MBMB) 2000
Flood prone Area (Polygon)	State Geospatial Data Centre (SGDC) is a fundamental dataset development projects based on five (5) theme of the document dataset based on Malaysian Standard (MS1759). Dataset Inland Flood Prone Area P SGDC Melaka project involving data from the Department of Town and Country Planning Malacca. The format of this data is in the form (. Tabs).
Building Location (Point)	This data was published by Geodata Development Branch (National Framework Section), in order to complement MaCGDI geospatial data SGDC Malacca. Layer Building_Educational_P data is in the form of a point (Point). Scale is 1: 10,000.

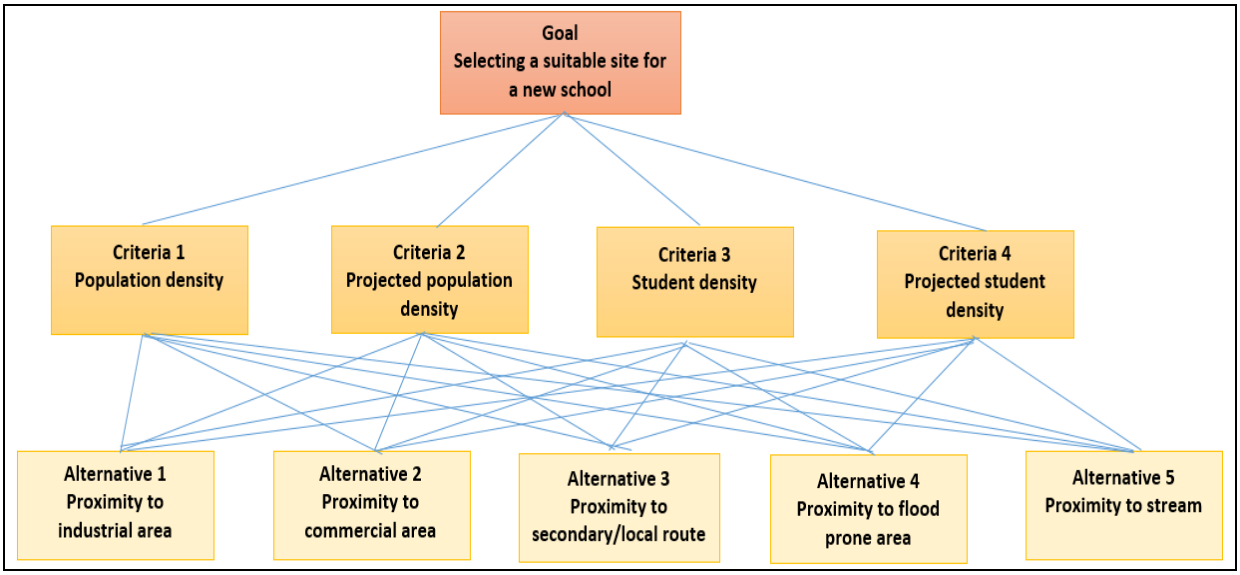


Fig. 3 - Analytical Hierarchy Process (AHP) and Pair Wise Result

By using the AHP, weighting score for every each criterion is derived by directly comparing the importance of one criterion to another criterion. For each criterion weightage, relative important was set out through discussions and interview with a group of expertise using AHP and pair wise comparison.

Table 5 - Site Suitability Evaluation Criteria Description of score

Analysis	Criteria	Weightage
School Demography Analysis (0.5)	Population Density	0.25
	Projected Population Density	0.25
	Student Density	0.25
	Projected Student Density	0.25
School Safety Analysis (0.5)	Distance from industry area	0.29
	Distance from commercial area	0.20
	Distance from main road	0.23
	Proximity to Flood prone	0.14
	Distance from stream	0.15

3.5 Choice Phase

The final 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 (Table 6). For this last phase, accessibility approach was used to identify the most suitable school. Accessibility refers to how easy is to go to a site.

Table 6 - Accessibility Evaluation Criteria Description of score

Analysis	Criteria	Classification	Standardization of Score (X_y)	Weight (W_m)
Accessibility Analysis	Distance from Public Facility	0 - 500	4	0.717
		500 - 1000	3	
		1000 – 1500	2	
		> 1500	1	
	Distance From Mosque	0 - 500	4	0.283
		500 - 1000	3	
		1000 – 1500	2	
		> 1500	1	
			Total Weight	**1.0**

4. Results and Discussions

From school need analysis, the required number of school is obtained. Using population approach, the number is estimated to 20 schools for whole Melaka Tengah District. The county which requires a relatively high number of schools is Mukim Bachang, Mukim Batu Berendam and Mukim Tanjung Minyak.

Demography analysis is the first analysis performed. It is important to view the appropriate distribution of current and future residents to ensure the school can accommodate population and students. From demography analysis, area with less population is located at the north part of the study area probably because it is too far from infrastructures and public services, which is definitely not suitable for housing development and education. Area with high population density is focused on the central of the study area.

Then, safety analysis is done by considering 5 factors to locate the new school. This analysis is important to identify and review schools that are exposed to the environmental risk and also finding the most suitable location or area for school sitting. The safe and healthy environment lies far beyond the central part of the study area. The safety analysis map is then overlaid with existing school and resulted 41 schools in unsuitable and unsafe zone (score 1 and 2). The result is not differing from studies performed by the MOE in 2013. It is found that 24 schools in the Melaka Tengah District experiencing environmental issues such as sharing border and road with industry area or in city center central business district (CBD). These schools located in the downtown area around the Bandar Melaka County which is not much differing from the output analysis that has been done.

Next phase was conducting constrain analysis by taking three factor into accounts which is proximity to historical site, swamp and existing school. These analyses show the availability of area for school development which resulted 46% of the total area is in suitable zone and 54% of the study area is not suitable for school development mainly because it's located too near to the existing school. A school that is too close with the existing school might contribute to overpopulation density and generate traffic congestion. JPBD and MOE have stated that a buffer zone of 1 to 1.6 km radius must be assign to existing school if new school is to be developed.

In the last phase of finding a suitable area for new school, an accessibility analysis has been done. This analysis is very important to ensure the new school will be close to the public services, library and community center to facilitate student and teacher to get the material for education and learning process.

The result of suitability analysis indicate that distance from industrial, commercial and road are the most challenging and critical factors to consider when selecting the most suitable area to develop a school. Fig. 6 shows the suitability map generate only 12.87% (3823.08 ha) of score 4 which indicate a highly suitable area for school development. Most of the highly suitable area is scattered among high density county such as Balai Panjang, Bachang, Peringgit, Bukit Katil, Bandar Melaka, Kelebang Besar, Duyung, Cheng, Tanjung Minyak and Batu Berendam. This is due to tremendous development in the study area and lack of land availability has affected the potential school locations. MOE and MBMBB should discuss about this matter seriously because the population of students will be increasing in the year of 2020

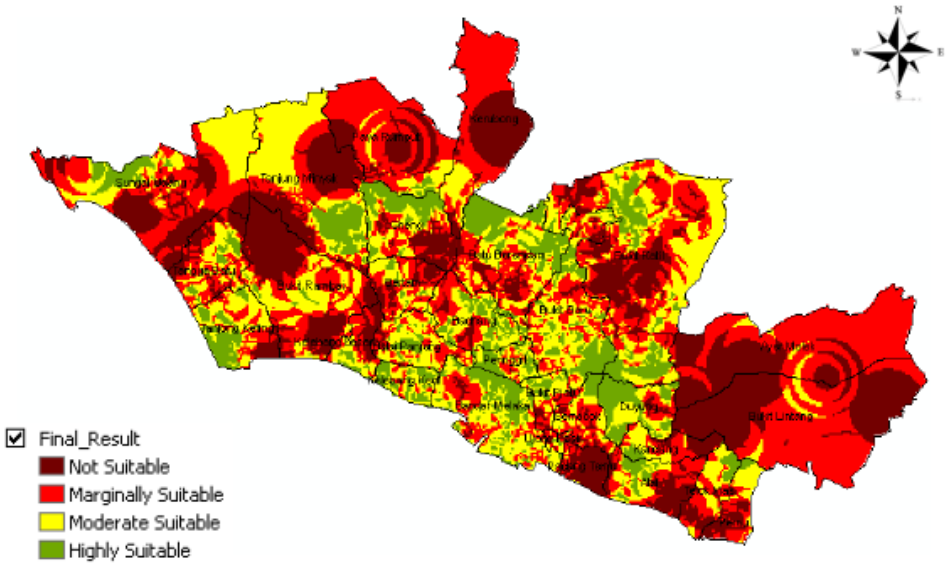


Fig. 6 - Suitability Map

5. Conclusion

The GIS based multi-criteria analysis method has been utilized to build up the school site selection that is introduced in this study. The study and its outcome explain the succesfull performance and advantages of applying the GIS technology for education planning and decision making process. The utilization of GIS technology dependant on displaying for decision support system has made new abilities and advance help to the planning process. GIS is not just an analytical tool but also a tool to assist planners and administrators to make decisions and it is realizing the ground reality visually. In this manner, GIS-based analytical technology has solid prospects to give the practical answer for spatially related problems. Thus, the research is capable to increase the opportunity of access and the quality of education facility of the society. Subsequently, it was possible to recognize most suitable for locating schools in the area. Where the study area divides according to the proposed criteria and weights to three classes good, medium and bad. The final suitability map indicates that 38% (11367.47 ha) of the study area is suitable (good location) for a school site, and 26% (7706.81 ha) of the study area under highly not suitable.

Acknowledgement

The authors would like to acknowledge the Centre of Applied Geomatics for Disaster Prevention, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat, and Tropical Map Research Group, Faculty Geoinformation and Real Estate, Universiti Teknologi Malaysia, Skudai, Malaysia

References

[1] Elsheikh, R. F. A. (2017). Multi-criteria decision making in hotel site selection. International Journal of Engineering Science Invention, 6, 15-18
[2] Bukhari, Z., Rodzi, A. M. & Noordin, A. (2010). Spatial multi-criteria decision analysis for safe school site selection. International Geoinformatics Research and Development Journal, 1(2), 1-14
[3] Take 5 (2018). Malaysia Budget 2019. EY Publications
[4] Prasetyo, D. H., Mohamad, J. & Fauzi, R. (2018). A GIS-based multi-criteria decision analysis approach for public school site selection in Surabaya, Indonesia. Geomatica, 72(3), 69-84
[5] Aziz, A. (2004). Spatial Decision Support System for School Siting. Doctoral Dissertation, Universiti Putra Malaysia
[6] Jayaweera, K. N. (2016). Application of Geographic Information Systems for Government School Sites Selection. Doctoral Dissertation, University of Sri Jayewardenepura
[7] Yoon, Y. G. (2017). A Study on the effect of school site planning factors related to school location on increase and decrease of the number of students in Korea. The Journal of Sustainable Design and Educational Environment Research, 16(1), 20-29
[8] Longley, P. A., Goodchild, M. F., Maguire, D. J. & Rhind, D. W. (2005). Geographic information systems and science. John Wiley & Sons

[9] Jayaweera, K. N., (2016). Application of Geographic Information Systems for Government School Sites Selection. Doctoral Dissertation, University of Sri Jayewardenepura
[10] Daneshvar, M. R .M., Khatami, F. & Shirvani, S. (2017). GIS-based land suitability evaluation for building height construction using an analytical process in the Mashhad city, NE Iran. Modeling Earth Systems and Environment, 3, p. 16, https://doi.org/10.1007/s40808-017-0286-z
[11] Blagojević, B., Jonsson, R., Björheden, R., Nordström, E. M. & Lindroos, O. (2019). Multi-criteria decision analysis (MCDA) in forest operations–an introductional review. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering, 40(1), 191-2015
[12] Malczewski, J. (2006). GIS-based multicriteria decision analysis: a survey of the literature. International Journal of Geographical Information Science, 20(7), 703-726
[13] UNESCO (2013). International Institute for Educational Planning. http://www.unesco.org/education/pdf/11_200.pdf
[14] Melaka City Council (2010). Special Area Plan: Malaka Historical City conservation Area Management Plan (Rancangan Kawasan Khas: Pelan Pengurusan Kawasan Pemiliharaan Bandaraya Melaka Bersejarah). Town and Country Planning Department, Melaka
[15] Ministry of Education (2013). Educational System Policy. http://www.moe.gov.my/en/sistem-pendidikan
[16] Österman, A. (2014). Map visualization in ArcGIS, QGIS and MapInfo. KTH Royal Institute of Technology
[17] Bukhari, Z., Rodzi, A. M. & Noordin, A. (2010). Spatial multi-criteria decision analysis for safe school site selection. International Geo-informatics Research and Development Journal, 1(2), 1-14
[18] Aziz, K. A. & Siang, T. G., 2014. Virtual reality and augmented reality combination as a holistic application for heritage preservation in the Unesco World Heritage Site of Melaka. International Journal of Social Science and Humanity, 4(5), 333-338
[19] Malczewski, J. (1999). GIS and Multicriteria Decision Analysis: John Wiley & Sons
[20] 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
[21] Town and Country Planning Department of Peninsular Malaysia (1997). Planning Guidelines JPBD 19/97. http://www.townplan.gov.my
[22] Vermont Department of Education (2005). Vermont School Construction Planning Guide. http://education.vermont.gov/new/pdfdoc/pgm_construction/guide_06_0707.pdf
[23] Wind, Y. & Saaty, T. L. (1980). Marketing applications of the analytic hierarchy process. Management Science, 26(7), 641-658
[24] Li, Z., Fan, Z. & Shen, S. (2018). Urban green space suitability evaluation based on the AHP-CV combined weight method: A case study of Fuping County, China. Sustainability, 10(8), p. 2656, https://doi.org/10.3390/su10082656