Integration of GIS and Multicriteria Evaluation for School Site Selection
A Case Study of Belgut Constituency

Philip Kiprono Talam* and Moses Murimi Ngigi

Abstract- Site selection is a complex problem that involve, technical, political social, environmental and economic demands that are difficult to satisfy via one method which may be in conflict with others. Schools need be located on safe places; these safe locations should also be optimal and economical to the public in terms of accountability. Location of these schools has always been done without use of any scientific methods and has led to sprouting of schools located in unsuitable locations. The study area, Belgut Constituency in Kericho County, has schools with less than minimum land size, over enrolment and close to flood prone areas. This was due to lack of regulations on establishment of new emerging schools. Hence there is need to use combination of Geographical Information Systems (GIS) tools and multi criteria evaluation (MCE) methods in locating them in the most suitable location. This way, incidences of congested, dangerous locations, underutilized schools and human bias will be eliminated. The research study objective was to locate the physical site for any school using GIS technology integrated with Analytical Hierarchy Process (AHP), a tool in MCE for finding a suitable location of any new school. Also a weighted overlay method, a tool in ArcGIS, was used to combine all the identified criteria and the results indicated that there are suitable and economically viable areas to add new schools to the eastern part of Belgut which totals to 32 Ha with a small part falling in the central and south western part. From the results it was recommended that in locating new schools the management should embrace use of GIS technology integrated with MCE methods in locating their new schools effectively economically and socially. The authority concerned with school location and safety need to make and published a preferred criteria for use in Kenya.

Key words-suitability analysis, MCE, AHP

I. INTRODUCTION

Prioritization requires general and diverse economic, social, political, environmental, cultural and other criteria that reach beyond the familiar process of deciding on the best alternative in making a single decision. Decisions about decisions are more difficult as the best choice for each particular decision is often unknown requiring a large amount of time and resources to determine. [1]

A school site need to meet some conditions and hence the need to locate them on suitable locations and this research aims to apply systematic procedures to obtain the most suitable location as is proposed in the District Focus for Rural Development [2] and obviously as a way of scientific justification of a preferred location for a school. This research project will zero in to a case study of siting primary schools in Belgut constituency with the endeavour to find optimum site for schools which are economically viable and safe.

GIS is used to identify candidate sites for new primary schools. The procedure followed under a GIS framework rejects the unacceptable sites considering pre-determined factors exclusively, contained in the form of multiple layers of attribute information to select the candidate sites.

It also requires some framework like minimum and maximum distance between schools, roads, rivers, towns or factories if any and capacity versus land size of existing schools. In this application, GIS is a screening tool in a site selection process to narrow the number of candidate sites, subsequently leading to one or more suitable sites for a school

Development projects are often located by undefined means sometimes just because money or space is available and continuity is not obvious since projects are not mapped on regular interval to easily visualize the spatial distribution and expansion. Using modern ways of site location would also benefit the entire region uniformly not depending on regions where decision maker's supporters come from. Other problems include the lack of adequate awareness by the public, evaluation, political leaders picking the part of management committee yet they are signatories themselves obviously poses conflict of interest. Scientific decision making could be a solution.

In the struggle for equity and poverty reduction universal free primary education was introduced and has increased enrolment by over 1.5 million pupils since 2003, currently there are 4,215 schools to cater for about 3.2 million school-age children. It will, therefore, be necessary to build additional schools and provide support to children from vulnerable households. [3].The potential to start new schools, funded through devolved funds and the community threatens the efficient use of resources in education sector. There has been efforts to improve the quality of school infrastructure and also to start new schools, mainly through Constituency Development Funds, and community support financing but

Phillip Kiprono Talam, Institute of Geomatics, GIS and Remote Sensing (Email address: Philip.talam@gmail.com)
Moses Murimi Ngigi, Institute of Geomatics, GIS and Remote Sensing

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new unplanned school facilities continue to put a strain on available inputs, especially teachers.

There is need therefore, to ensure that devolved funds are not used to start "small schools", which cause further inefficiencies in the system, but for the most over-crowded schools. Achieving national objectives with decentralized funds remains a challenge .The safety standards manual for schools in Kenya has considered safety inside school compound [5] and hence the need to input automated siting techniques like GIS technology to improve on this. Modern technologies are not embraced like the field of ICT and schools location is not systematic since multi criteria evaluation to determine hierarchy of factors is not a common practice in school site selection which would emphasize on the most suitable sites as per a combination of policies and conditions such as safety, population, poverty levels, accessibility, availability of man power like teachers in this case, terrain and the coverage/hinterland.

The study's main objective is to demonstrate the ability of GIS in locating schools basing on suitability analysis using multi criteria evaluation (MCE) approach. It involves exploration of the use of GIS technology integrated with MCE method in supporting decision making for suitable school locations. Development of a database of the primary schools and the location model using weighted overlay method are the major tasks in this endeavour.

Spatial scope of the research is the Belgut constituency in Kericho County (Fig.1) which is mainly an agriculturally rich area with Tea and dairy farming as her major income earner.

Automation has been lauded in many sectors like in engineering and production firms. GIS is a most recent and reliable tool and inevitably of great use in this modern world and the fast changing technology and need be embraced. Indeed geospatial mapping of development projects is a way of managing and monitoring fair and safe locations of schools but not much is being done on multi criteria evaluation. GIS technology is cost effective, efficient, and accurate and eliminates human bias in location of new schools. The vision 2030 acknowledges that GIS is a tool of importance in achieving the goals in a wide number of applications like economic, social and political governance. The school safety standard has concentrated on the safety inside the compound hence a look at external factors for school location appears a gap and is part of the basis for this research.

Suitability Analysis is the process and procedures used to establish the suitability of a system, that is, the ability of a system to meet the needs of a stakeholder or other user. Suitability analysis in a GIS context is a geographic, or GIS-based process used to determine the appropriateness of a given area for a particular use. The basic premise of GIS suitability analysis is that each aspect of the landscape has intrinsic characteristics that are to some degree either suitable or unsuitable for the activities being planned. Suitability is determined through systematic, multi-factor analysis of the different aspect of the terrain. Model inputs include a variety of physical, cultural, and economic factors. The results are often displayed on a map that is used to highlight areas from high to low suitability [7].

A GIS suitability model typically answers the question, "Where is the best location?" Whether it involves finding the best location for a new road or pipeline, a new housing development, or a retail store. For instance, a commercial developer building a new retail store may take into consideration distance to major highways and any competitors' stores, then combine the results with land use, population density, and consumer spending data to decide on the best location for that store.

A number of suitability analysis using the proposed method has been conducted: [8]-[10] and [12]-[13].

The Kenyan government has historically responded to the emerging social and public problems through establishment of various decentralized financing mechanisms to redress the underlying causes of the problems [11]. The struggle to develop the country involve development projects that may be decentralized and need fair distribution and on suitable locations.

In a site selection exercise, the analyst strives to determine the optimum location that would satisfy the proponents' selection criteria. The selection process endeavours to optimize a number of objectives desired for a specific facility which usually involve a number of decision factors that are often contradicting and as a result, the process often involves a number of possible sites of which, each has advantages and limitations.

Suitability analysis is a GIS-based process applied to determine the suitability of a specific area for considered use. It reveals the suitability of an area regarding its intrinsic characteristics (suitable or unsuitable).The combination of spatial Analytical Hierarchy Process method as one of the commonly used methods of spatial multi criteria analysis (SMCA) with GIS is a new trend in land suitability analysis. [8].

There exists a number of approaches applied in suitability analysis such as the Geographically Weighted Regression (GWR), the Spatial Analytical Hierarchy Process (AHP) Method (SAHPM) and MCE. The MCE method used, weighted overlay, requires that all factors be standardized, or transformed into units that can subsequently be compared [14].

Building of new schools entails planning and mapping of old schools to make sure that some areas don't have more schools than they need at the expense of others and GIS can offer the best maps for both the existing and the expected school locations. Mapping of population versus schools or versus literacy level of the Kenyan society would assist the government come up with the best locations of new schools[6]

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A. Analytical Hierarchy Process

Analytic Hierarchy Process (AHP) is one of the most commonly used MCE tools. AHP is a method that allows the consideration of both objective and subjective factors in ranking alternatives. Since its introduction in the mid-1970s by Thomas Saaty, A paper in the Journal of Mathematical Psychology [15].precisely described the method. AHP is a method for ranking decision alternatives and selecting the best one when the decision maker has multiple criteria [16].

Since its introduction, AHP has been widely used for example in banks, manufacturing systems, operator's evaluation, site selection, software evaluation, evaluation of website performance, strategy selection, supplier selection, selection of recycling firms competence evaluation , weapon selection , underground mining method selection and its sustainability , software design , organizational performance evaluation , staff recruitment, warehouse selection, technology evaluation, route planning, project selection ,customer requirement rating , energy selection and university evaluation [17] , construction method selection [18] and many others. Several papers have compiled the AHP success stories such as [19]-[26].

In AHP, preferences between alternatives are determined by making pairwise comparisons. In a pairwise comparison, the decision maker examines two alternatives by considering one criterion and indicates a preference. These comparisons are made using a preference scale, which assigns numerical values to different levels of preference [27]. The standard preference scale used for AHP is 1-9 scale which lies between equal importance to extreme importance. Therefore, if the importance of one factor with respect to a second is given, then the importance of the second factor with respect to the first is the reciprocal. Ratio scale and the use of verbal comparisons are used for weighting of quantifiable and non-quantifiable elements [28].

The AHP enables the decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environment in conflict. The application of the AHP to the complex problem usually involves four major steps [29]:-

1. Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form- problem modelling.
2. Make a series of pair wise comparisons among the elements according to a ratio scale - weights valuation.
3. Use the eigenvalue method to estimate the relative weights of the elements- weights aggregation.
4. Aggregate these relative weights and synthesize them for the final measurement of given decision alternatives- sensitivity analysis

B. Consistency of judgment

As priorities make sense only if derived from consistent or near consistent matrices, a consistency check must be applied. [15] proposed a consistency index (CI), which is related to the eigenvalue method:

$$CI = \frac{\lambda_{Max} - n}{n-1} \quad \text{--1}$$

Where;

n= number of factors

λ_{Max} =maximal eigenvalue = the sum of products between each element of the priority vector and column totals

The consistency ratio, the ratio of CI and RI, is given by:

$$CR = \frac{CI}{RI} \quad \text{--------------------------------2}$$

$$S = \sum W_i X_i X \prod c_j \quad \text{-----------------------------3}$$

S =is the composite suitability score

X_i =Factor scores (cells)

W_i =Weights assigned to each factor

c_i =Constraints (or Boolean factors)

Σ=Sum of weighted factors

∏ -Product of constrains where the digit 1 refer to suitable and 0 refer to unsuitable.

RI stands for random index and represents an average CI for a huge number of randomly generated matrices of the same order. It is an expected RI, so CR is the ratio between the consistency index and the expected one hence the bigger it is, the worse the data, by that measure. Usually, RI is not computed instead tables are used.

The concept of consistency, along with the consistency index, the random index, and the consistency ratio, was proposed by Saaty who calculated the random indices [15], (Table 1)

Table 1 random indices

n	3	4	5	6	7	8	9	10
RI	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

From Saaty, 1977

C. Parameters for suitability analysis

Expert opinion was critical in this phase, Literature review of various references, interviews with experts from National Environmental Management Agency (NEMA), and a look at available data helped in identifying the critical requirements for suitable site for a school as follows.

1) Proximity to Major Roadways

The site should not be adjacent to a major road or freeway that any site-related traffic and sound level studies have determined would have safety problems or sound levels which adversely affect the educational program. Trucks on public roads release hazardous smoke and have a greater incidence of accidents, spills, and explosions. When evaluating a site near a major roadway, a schools administration needs to evaluate risks by doing an environmental impact assessment.

Highway setbacks from schools are not established in law. However, experience and practice indicate that distances of at

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least 150 m are advisable as per expert interview although this varies so much depending on traffic levels.

2) Noise

Noise is unwanted since it is harmful. Too loud noise is distracting or, worse, injurious. The sound measured at 30 decibels is ten times as loud as the 20 decibel whisper. The normal range of conversation is between 34 and 66 decibels. Between 70 and 90 decibels, sound is distracting and presents an obstacle to conversation, thinking, or learning. Above 90 decibels, sound can cause permanent hearing loss. [31]

In determining whether noise is loud, unreasonable, unnecessary or unusual, the following factors may be considered-

(a) Time of the day
(b) Proximity to residential area
(c) Whether the noise is recurrent, intermittent or constant
(d) The level and intensity of the noise
(e) Whether the noise has been enhanced in level or range by any type of electronic or mechanical means
(f) Whether the noise can be controlled without much effort or expense to the person making the noise.

The Kenyan case is manned by NEMA gazette regulations. No person shall use or operate any radio or receiving set, musical instrument, phonograph, television set, any other machine or device for producing or reproducing sound or any other sound-amplifying equipment in a loud, annoying or offensive manner such that the, noise from the device;

a) Interferes with the comfort, repose, health or safety of members of the public
b) Creates a risk thereof, within any building or, outside of a building, at a distance of 30 meters or more from the source of such sound, or
c) Interferes with the conversation of members of the public who are 30 meters or more from the source of such sound. [32]

However noise mapping has concentrated in towns like Nairobi, Mombasa, Kisumu and Eldoret. An interview with a GIS expert in NEMA claims that the area of study is ‘quit quiet’.

Basing on the theoretical understanding and the environmental expert advice dummy data was generated covering the study area. This was generally found to be high along main road, towns and near factories.

3) Air pollution Index

Table 2: Air Pollution Index

Air Quality Index (AQI) Values	Levels of Health Concern	Colours
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

Source-EPA

The API is based on five pollutants: ground-level ozone, particulate matter, carbon monoxide, sulphur dioxide, and nitrogen dioxide.

This is also controlled by NEMA though the regulations in Kenya have not been gazetted. The study area also has no data and basing on literature available, dummy data was used. The United States Environmental Protection Agency (EPA) has developed an index called the Air Quality Index which they use to report daily air quality (table 2). This AQI is divided into six categories indicating increasing levels of health concern. An AQI value over 300 represents hazardous air quality whereas if it is below 50 the air quality is good. [33]

4) Proximity to High-Voltage Power Transmission Lines

Electric power transmission lines maintained by power companies may or may not be hazardous to human health. Research continues on the effects of electromagnetic fields (EMF) on human beings. However, sites should be done with caution about the health and safety aspects relating to overhead transmission lines. Most departments of health recommend a minimum of 107 meters from edge of way leaves [34].The high tension power line is one of 400Kv that requires a way leave of 60 meters.

5) Proximity to flood areas

The study area is generally hilly hence not much effect is caused by flood and flood data was unavailable for the study area and information basing on the last floods via interviews showed that the worst was in 1961 of which one river busted its banks and one school was closed since it was submerged.

6) Proximity to streams

Water is important resource for school children, however locating schools close to streams may be disastrous since flash floods and water pollution may occur and children will be affected. Experts recommend a minimum of 150 meters away from the shores. Stream data was captured from topographical sheets from survey of Kenya.

7) Proximity to factories

Factories emit fumes and are also noisy and surrounding it may be residential area for the workers and unplanned centre is bound to sprout. Expert recommends a minimum distance of 500 meters from the factory as a safe distance for a school location.

8) Proximity to other schools

Distance to other school based on how far a pupil should walk to school is a major factor in school location. Ministry of Deduction experts recommended one to two kilometres as a minimum walking distance. Existing schools data was sourced from schools mapping project and Kericho West education office.

9) Distance from towns

The study area has small towns spanning 100 meters in diameter with main push factors of school location being noise from garages, posho mills and the dangers of traffic. Data of towns were from topographic maps sourced from survey of Kenya supported by ground picking.

10) Slope

Good school site is on fairly flat field to enable children play comfortably, they will also have easy access to schools and construction cost reduced. Above 300 slope was not recommended.

11) Proximity to schools with expansion space

Some schools may have plenty of space for expansion compared to the enrolment like one stream requires 320 students and a space of 2.4 acres, therefore a school with one stream and a space of 4.8 acres may need expansion instead of starting a new school in the proximity. Other schools may be over crowded. This is basically for economic purposes.

12) Population density

Public fund need be optimally utilized hence school location in a highly populated area benefits many and it's also axiomatic that highly dense areas need more school to serve the high population. Density data was sourced from KNBS and interpolated to form a continuous surface.

II. METHODS AND MATERIALS

1 Study area

Belgut constituency in Kericho County. Borders Kisumu, Homabay and Nyamira counties to the west, Bureti district to the south and Ainamoi constituency to the North. (Fig 1) It is composed of 30 sub locations with a total population of 147188 and 123 public primary schools. Major economic activities are tea growing and dairy farming.

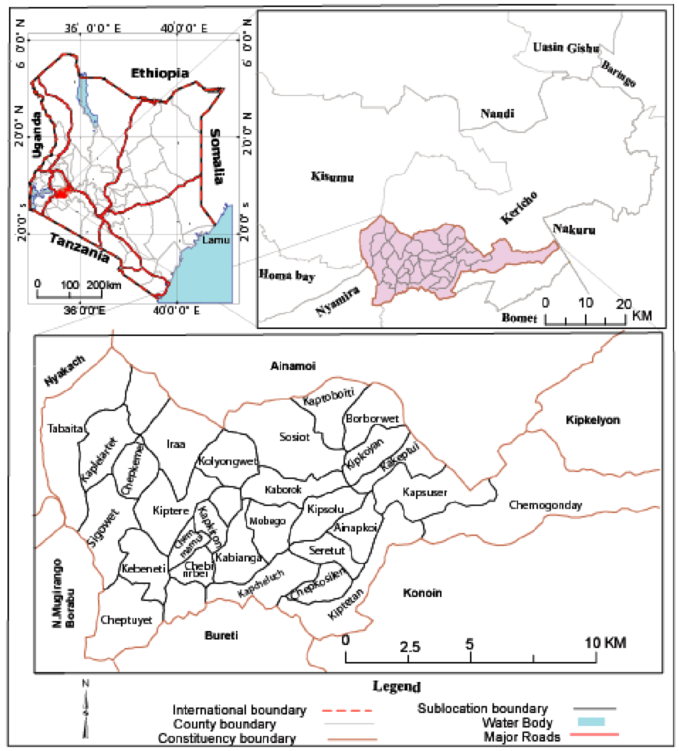

Fig 1: Location of Belgut constituency

2. Research flow

The research data was split into two; the spatial data and non-spatial data. Spatial data includes the base maps like the topographical sheets and DEM vectorized to obtain the contours, flood plains. Some data was already in vector format like the rivers, roads, towns and some of the existing schools from schools mapping project. Other spatial data were picked on the ground like the high tension power line and factories. Air pollution were interpolated basing on factors like proximity to factories and major roads due to emission of fumes like carbon and bad smell. Sound levels were also interpolated basing on proximity to the same roads, factory and towns.

Non spatial data included the expert questionnaire, existing documents like the school manual for Kenyan schools, size of land available in each existing school versus enrolment and other literature on school site suitability (Fig 2)

Based on the expert opinion via expert interview, a specific suitability level per factor was defined. In the procedure for MCE using weighted overlays, it was necessary that the weights sum to 1. In this study, the factor maps were ranked according to Saaty's underlying scale with values 1 to 9 by interviewing education specialist and literature reviews. Using Pairwise Comparison Matrix, factor weights were calculated by comparing two factors at a time. The Pair Wise Comparison Method (PWCM) were applied using a scale with values from 9 through 1 to 1/9 [30]. A rating of 9 indicates that the factor is more important than that paired with. On the other hand, a rating of 1/9 indicates that the factor is less important.

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For purpose of weighted overlay, spatial and non-spatial data were harmonized to same scale from score one to four where not suitable was assigned 1, less suitable-2, suitable-3, and most suitable-4 and factor layers generated in ArcGIS. SAHP a tool in MCE was then used to rank them and via a model suitable school locations generated (Fig. 3).

2 Data collection

The following parameters were identified and used for school location; distance from factories, distance from towns, distance from the main road, air pollution, noise level, gradient of terrain, flood prone areas, distance from stream, distance to schools with/without expansion space, distance from high voltage electrical transmission line, population density and distance to existing schools. Data collection was from various organizations which included NEMA, Ministry of Lands Housing and Urban Development, Ministry of Education, Kenya National Bureau of Statistics, desktop study and the expert interview. Some data were unavailable like the noise maps, air pollution index maps and the flood maps and dummy data were generated basing on expert interviews coupled with information from literature and guidelines that have been done in other countries.

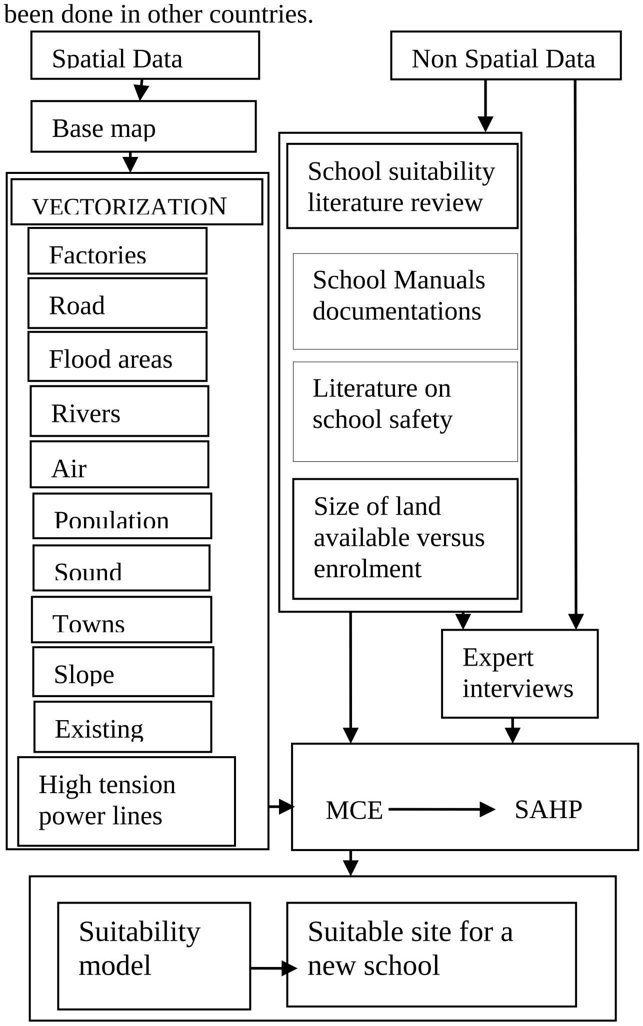

Fig. 2: Flowchart

Table 3: Suitability tolerance

Suitability tolerances	Suitability	class
High tension power		
0-150	1	Not suitable
150-300	2	less suitable
300-450	3	Suitable
>450	4	Most suitable
proximity to flood prone		
0-500	1	Not suitable
500-1000	2	less suitable
1000-1500	3	Suitable
>1500	4	Most suitable
Distance from streams (M)		
0-150	1	Not suitable
150-300	2	less suitable
300-450	3	Suitable
>450	4	Most suitable
Day time sound level		
0-50	4	Most suitable
50-60	3	suitable
60-70	2	Less suitable
>70	1	Not suitable
API readings		
0-50	4	Most suitable
50-100	3	suitable
100-150	2	Less suitable
>150	1	Not suitable
Proximity to factory area		
0-500	1	Not suitable
500-1000	2	less suitable
1000-1500	3	Suitable
>1500	4	Most suitable
Distance from towns (M)		
0-300	1	Not suitable
300-600	2	less suitable
600-900	3	Suitable
>900	4	Most suitable
Proximity other schools		
0-1000	1	Not suitable
1000-1500	2	less suitable
1500-2000	3	suitable
>2000	4	Most suitable
proximity to school with		
0-2000	1	Not suitable
2000-3000	2	Less suitable
3000-4000	3	suitable
>4000	4	Most suitable
Proximity to main roads		
0-150	1	Not suitable
150-300	2	less suitable
300-450	3	Suitable
>450	4	Most suitable
Slope		
>30°	1	Not suitable
25°-30°	2	less suitable
15°-25°	3	Suitable
<15°	4	Most suitable
Population density (per sq.		

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Suitability tolerances	**Suitability**	**class**
0-200	1	Not suitable
200-300	2	less suitable
300-400	3	suitable
>400	4	Most suitable

3 AHP Ranking

Ranking of the criteria was based on expert opinion and available literature where three levels were and 12 sub criteria were identified (Fig.3).

4 Computation of weights

Data processing involved Vectorization then systematic formation of the model which included interpolation, generation of euclidean distances, clipping, reclassification and weighting via weighted overlays tool using the composite suitability score.

The layers were each classified into four zones ranging from 1 to 4 where 4 represent cells on most suitable layers and suitability reduces gradually to 1 representing cells of unsuitable regions (Table 3).

From the expert's opinion via interviews, the factor ratings were put to matrix format and using Excel software were normalized by dividing the cell value by its column sum and priority vector (weights) obtained by determining the mean value of each row. Priority matrix are then computed and further used to compute the Eigen vectors and CR (equations 1 to 3)

To normalize the values, the cell value is divided by its column total and to calculate the priority vector or weight, the mean value of the rows is determined. For level two rankings, the procedure is the same as that of level three.

5 Procedures in ArcGIS programe

Vector data is processed using ArcGIS software by generation of Euclidean distances then classifying as per factor scores according to the experts' advice (Table 3)

The reclass tools provide a variety of methods that allow reclassification or change input cell values to alternative values.

The most common reasons for reclassifying data are to replace values based on new information, Group certain values together, Reclassify values to a common scale (for example, for use in a suitability analysis or for creating a cost raster for use in the Cost Distance function) or to Set specific values to No Data or set No Data cells to a value.

Finally weighted overlay tool is used to generate suitable sites for schools. Weighted overlay, overlays all the factors using a common measurement scale and weights each according to its importance (in this case common scale was 1 to 4 in each layer)

All input raster are integer since floating-point raster have been converted to an integer raster using the reclassification tools. Each value class in an input raster is assigned a new value based on an evaluation scale. These new values are reclassifications of the original input raster values. A restricted value is used for areas to be excluded from the analysis and finally each input raster is weighted according to its importance or its percent influence. The weight is a relative percentage, and the sum of the percentage influence (weights) must equal to hundred percent

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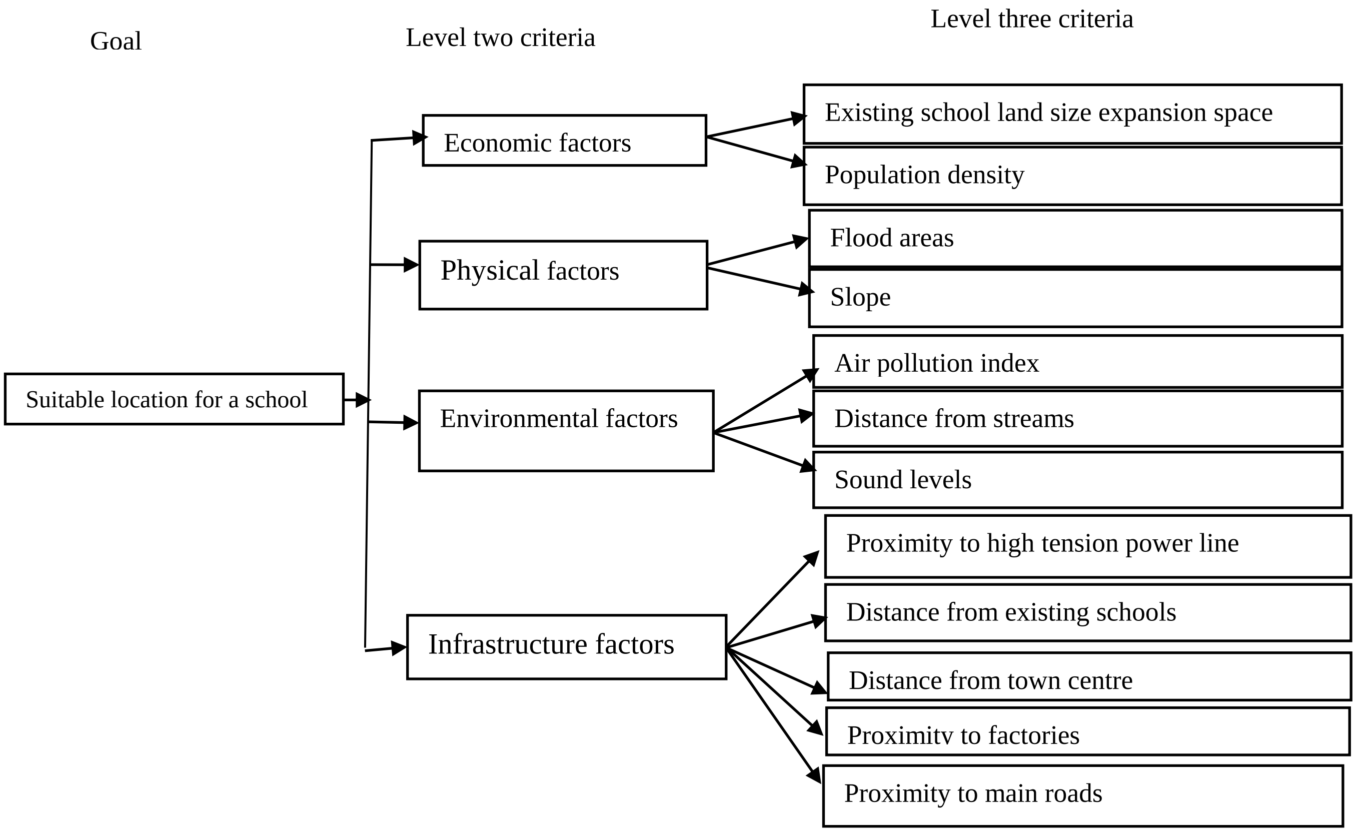

Fig.3: AHP ranking

III. RESULTS AND ANALYSIS

A. School site selection model

The study led to development of a suitable site selection for a school. The model was developed in such a way that the criteria is loaded into the geodatabase and its percentage influence including the restricted zones due to its existence keyed in the model and running it to yield an output which is a map showing optimum sites for a school.

The model is run in steps that zeroes in towards the goal starting from inputting the spatial data and classification of it .part of the model (Fig. 4) shows input as High voltage power line and it is converted to euclidean distance followed by reclassification and weighted overlay leads to identification of suitable site for a school

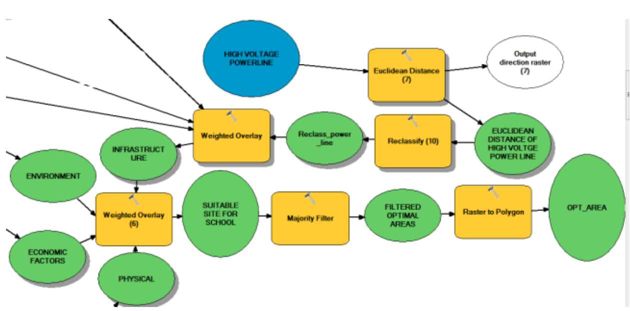

Fig. 4: Part of the model for suitable school site selection

B. Classified euclidean distances

The objective of the study is based on all analysis carried out and results are presented in form of maps and writing. A working model for suitable site selection for a school was developed from the twelve factors. The twelve layers were generated using ArcGIS software, Euclidean distance yielded a raster map with distance from the factors. They were then zoned (as illustrated in table 3-2) into four classes from restricted areas (1) to most suitable areas (4) according to proximity to factors generated via reclassify tools (Fig. 5 to Fig. 17). Of the123 public schools 21 fell on private plantations meant for the workers children (Chemogonday sub location) and 44 Schools were found to be of land size less than 2.4 acres and were eliminated from participation of finding suitable site for a new school.

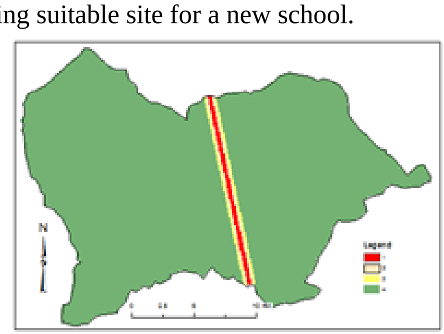

Fig. 5: Classification of distances to power line

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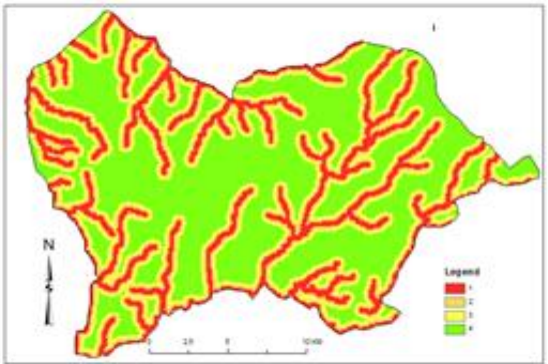

Fig. 6: Classification of distances to rivers

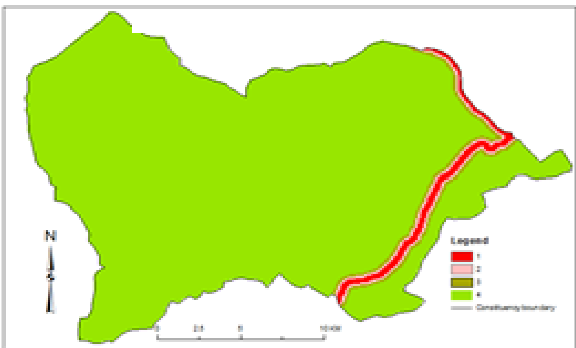

Fig.7: classification of distances to main roads

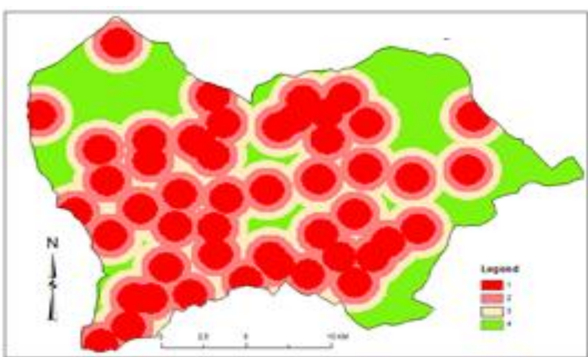

Fig. 8: Classified Euclidean distance to schools

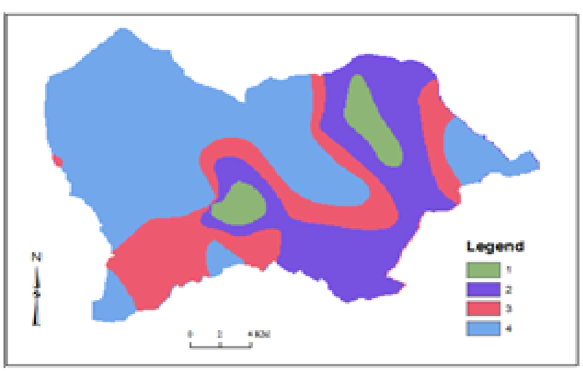

Fig. 9: Classified noise map

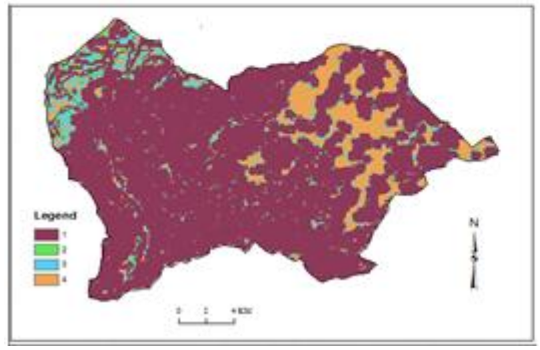

Fig. 10: Classified slope map

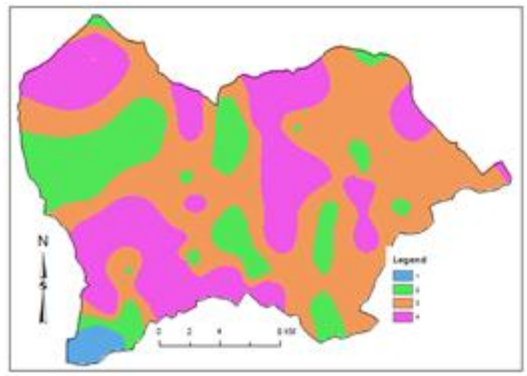

Fig.11: Air Pollution Index map

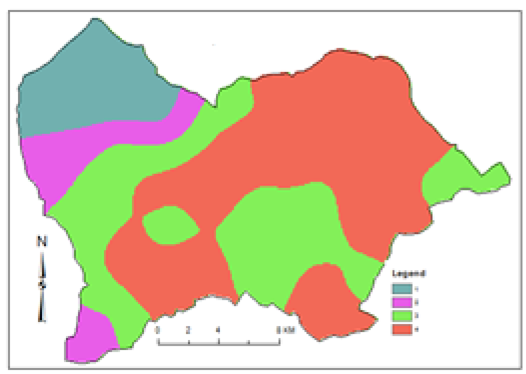

Fig. 12: Classified density map

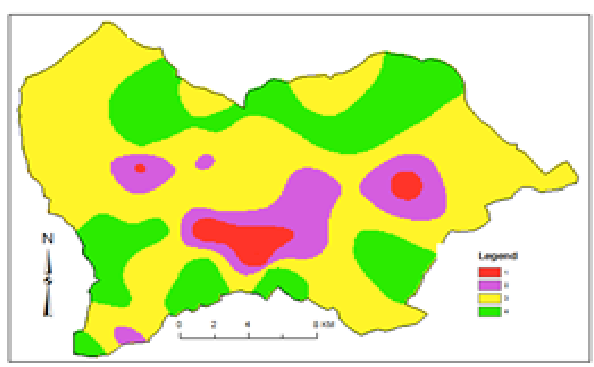

Fig.13: Classification basing on available expansion space

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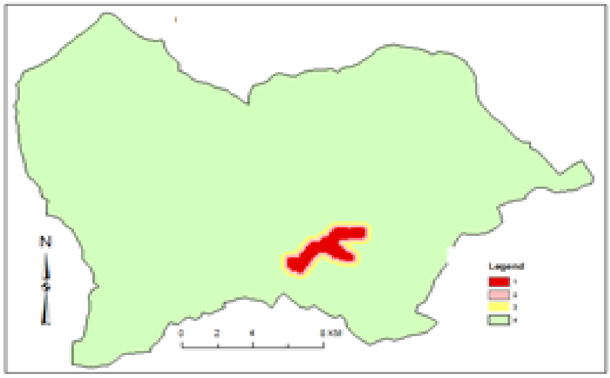

Fig. 14: Classification basing on flood areas

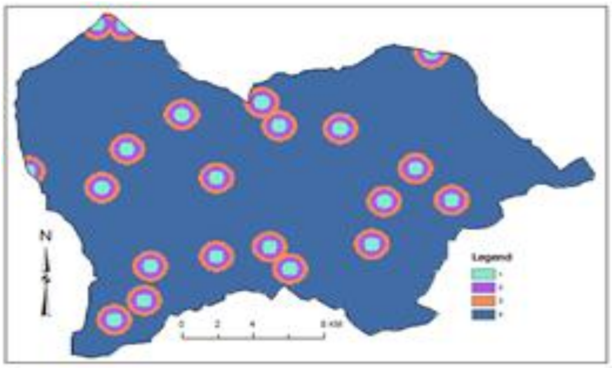

Fig.15: Classified euclidean distances to towns

Fig. 16: Euclidean distances to factory areas

C. Weighted overlays

Weighted overlay for level 3 factors (Fig. 17-Fig 20) clipped the restricted areas and a map with three zones in order of suitability level were returned.

Overlay of level two factors (Fig. 21) returned two classes of areas, the unsuitable and the suitable areas which on filtering by eliminating the suitable areas with too small sizes, the optimum areas for most suitable site were obtained (Fig. 22).

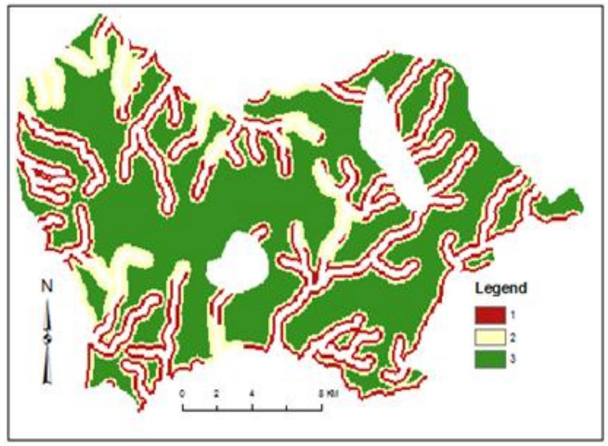

Fig.17: Weighted overlay of environmental factors

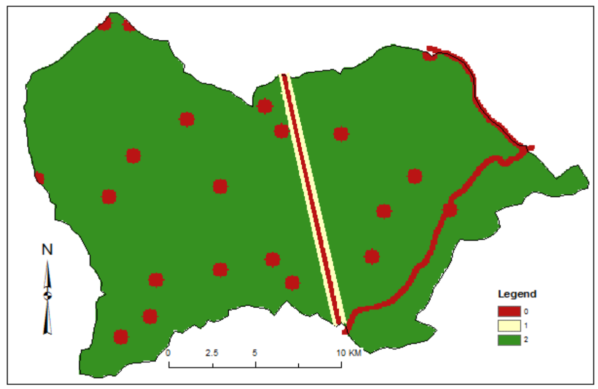

Fig. 18: Weighted overlay of infrastructures

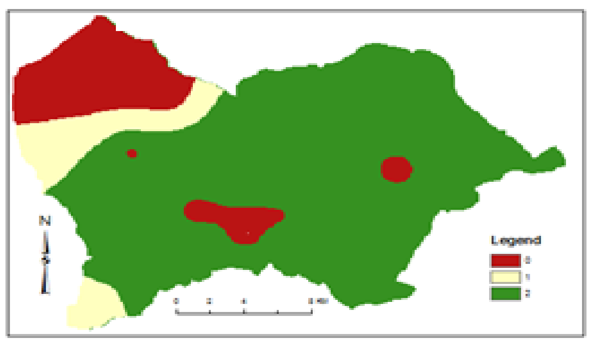

Fig.19: Weighted Overlay of economic factors

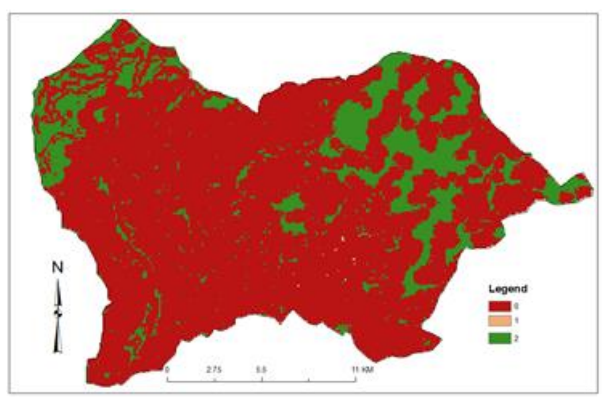

Fig.20: Weighted overlay of physical factors

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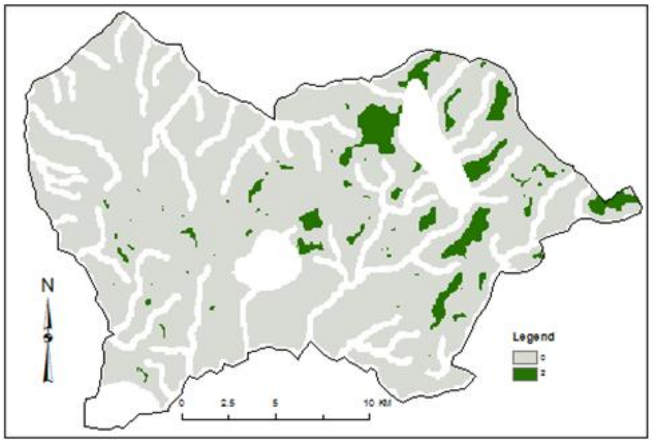

Fig. 21: Suitable locations for a school

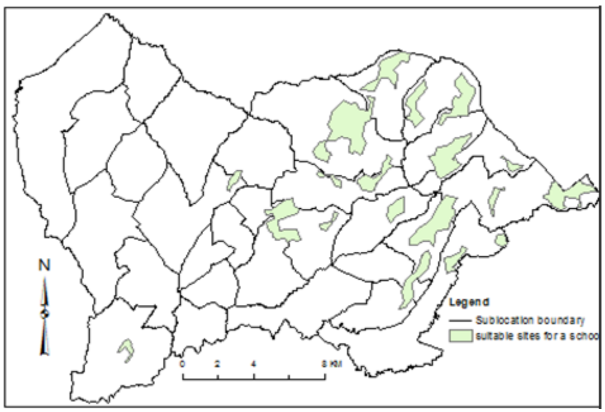

Fig.22: Optimum filtered locations

D. Capabilities of the model

This model can be used in any place provided that a criteria is first done and loaded to a geodata base.By dragging into the model and running it will return a map of all available sites for a school.The model is designed in ArcGIS and it can be edited and modified to suit various criteria and levels of ranking .The model developed is for twelve criteria and three levels of hierarchy.

It is paramount to locate a school in a save place however economic factors are brought in for planning and forcasting and to serve the public efficiently. By in putting expected future factors that can have been interpolated , planners can use the model for the future schools that may emerge due to population increase and emerging infrastructures.

E. Available suitable sites

32 ha were found to be in suitable places at the Eastern part of the constituency and the central part with very small area to the South western part of the constituency.This space can acommondate over 32 streams of 320 pupils each translating to a total of 10 240 pupils.

A check on this locations indicated that indeed some nine schools are located in them but are either in land size of less than 2.4 or are over populated and without space for expansion.while others (35) fell on the unsuitable sites.

Results indicated that Sosiot,Kipkoyan,Kaptoboiti and Borborwet sublocation have the most sutable site for a new school based on all the twelve criteria this is due to high population density,fairly flat terain and that schools around this place are already full with little or no room for expansion.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The existing schools were captured and put to a database in a personal geodatabase along with other feature and raster class data that made the criteria used to determine the optimal sites of a school. The methodology employed integration of GIS technology and AHP as an MCE tool to support decision making on school location.

There were 44 schools in the study area that had less than 2.4 acres of land for a single stream implying they were initiated without prior consideration of minimum size required. The results indicated that there are areas that are suitable and economically viable to add new schools to the eastern part of Belgut which totals to 32 Ha with a small part falling in the central and south western part. There were no systematic criteria for a school location and hence the model was developed basing on the experts' opinion and sourced from literature review. The model can reduce, incidences of congested, dangerous locations, underutilized schools and human bias will be eliminated.

B. Recommendations

Decision makers need to embrace this technology as is suggested in the Kenya vision 2030 and the role of GIS in meeting its goals, since it provides a scientific way of decision making and promotes fairness.

The weighted overlay successfully yielded logical results and can be used for similar research in future and can be incorporated into the Ministry of Education's school mapping project provided it is updated in a desired regular interval of time.

There is need for further research on education facility location to piece up the necessary locational criteria in Kenya so that site for new schools can be selected systematically and in a scientific method. A mechanism need be created to stop cropping up of new schools that do not meet the recommended standards like minimum land size and unsuitable locations.

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