Assessment of Schools Spatial Distribution and Identifying Suitable Areas by Using GIS Technology: In Case of Debre Markos Town North Western Ethiopia

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Abstract
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. To enhance an academic excellence and identify better school site this study applied GIS technology in Debre Markos Town, Ethiopia. In Debre Markos many schools characterized concentrate in centres, vulnerable for natural risk like flooding, near to noise areas, markets and rivers. The aim of this study was to assess the spatial distribution pattern, conformity of both national and international standards and indicate the future suitable areas of new school sites based on national and international standards of public primary and secondary schools in Debre Markos Town. Debre Markos Town located in the North-Western Part of Ethiopia. In Debre Markos Town populated more than 95,000 residents and 18 public primary and secondary schools. This study used both primary and secondary GIS data including filed survey, quick bird images, population and high-resolution satellite images from google earth. These data took form EMA (Ethiopian Mapping Agency, Debre Markos Town Municipality. Arcgis 10.4.1, DNGarmin and Google Earth used as a software packages for different geo-processing application and data calibration. The method totally used national and international standards to assess distribution, conformity and identify the suitable new school sites. The result revealed that 89% schools are located less than two kilometres far away than other schools and 11% are schools far away more than two kilometres than other schools. Around 11 or 61% schools located with 450 meters distance of road facilities the remaining 7 or 39% schools are located far more than 450 meters from road facilities. Endemata Primary School is the most unsuitable schools compare with to other schools. It was near to market centre, Wuseta River and noise area. For the future, not only schools but also other public facilities should apply national and international standard before the construction of schools and other public facilities. For the establishment and implementation of new school sites GIS has a vital role. Therefore, the government and urban planners should apply GIS technology to identify the suitable school site.

School facilities and distribution
Education is one of the most important tool of economic and social expansion and household livelihoods and food security status. Some quantitative studies indicated that investment on education strengthens the productivity in all the sectors of the economy much more than other levels of public sector, and that economic returns to investment on education are greater than those arising from other levels public sector investments (Irshad, 2016) To make such human capital development, needs full investment to build standard academic institution from primary to tertiary and research institutions. These academic institutions including schools need good environmental areas for better work and learning system. Thus, schools need be located on suitable location; these suitable locations should also be optimal and economical to the public in terms of accessibility. 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 (Bukhari. et al, 2010).

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 site selection locations and suitability of school’s sites. GIS technology is cost effective, efficient, and accurate and eliminates human bias in location of new schools (Osman K.et al., 2010) GIS technology can collect, store, integrating, analysing spatial referenced data. It enables that to implement, establish integrate, structured and good manner location placement of schools in the urban areas. This technology support to select the suitable and the appropriate location of infrastructure by integrating and considering both national and international selection site standards (Irshad, 2016).

GIS is used to identify candidate sites for new 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 (Umar.etal, 2015). 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 (Osman K.et al., 2010).

Planned location of schools, health centres, urban park areas, petrol stations, hospitals, drinking water lines, telecom lines are vital to enhance the living standard of the urban dwellers. In Ethiopia, most of these facilities are established without considering both national and international standards of school’s placement like UNSECO and Amhara National Regional State of Education Bauru. It is also common in Debere Markos Town mismatch location of these facilities.

There are many schools around on noise areas and vulnerable to traffic accidents on the adjacent of main roads. Some schools are also located on steep slope and rigid areas. Some schools also concentrate only in the centre of the town while others are far from the residence places of students.

By considering these problems, this study used GIS technology to assess the distribution, conformity and identify recommended suitable location of these facilities in Debere Markos Town. It enables that to in endorse the suitable sites for the location of schools. It will also provide information on the distribution and the relevance of the location of schools in this town.

1.2 Study Area
Debre Markos Town found in Amhara Regional State, East Gojjam Zone as a capital city (centre) of East Gojam Administrative Zone. It far from Addis Ababa (capital city of Ethiopia) 299 Kilometres in North West of Addis Ababa. Debre Markos town lies in rigid mountains area of north western high lands. Astronomically, the town is located between 10° 16.9' to 10°22.5' North Latitude and 37° 41.4' to 37°46.2’ East Longitude. Area of the town is expected to be 1214.9 sq. Km and 65.82 km/square density.

In Debere markos town, both public and private schools there are 17 KG, 23 primary schools, 3 high schools, 2 preparatory schools, 15 adult education schools, 11 different colleges and one University. Educational service buildings composed of all primary, secondary and a preparatory school owned by the city administrations is inventoried. A total of 179 old and new school buildings are registered covering a total area of 33,608.36 square meter of land.

In public, there are 18 school both in primary and secondary schools and covered around 32047.78-meter square of area.

Figure 1 Location of Debre Markos Town
Table 1 Public primary and secondary students in Debre Markos Town

<table>
<thead>
<tr>
<th>School</th>
<th>Location</th>
<th>School_Id</th>
<th>No Blocks</th>
<th>Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigus Tekel Haimanot Primary School</td>
<td>Kebele 04</td>
<td>SC_01</td>
<td>15</td>
<td>4509.03</td>
</tr>
<tr>
<td>Addis Hiwot Primary School</td>
<td>Kebele 05</td>
<td>SC_02</td>
<td>6</td>
<td>740.11</td>
</tr>
<tr>
<td>Yemeka Primary School</td>
<td>Kebele 04</td>
<td>SC_03</td>
<td>3</td>
<td>258.40</td>
</tr>
<tr>
<td>Debza Primary School</td>
<td>Kebele 03</td>
<td>SC_04</td>
<td>13</td>
<td>1954.28</td>
</tr>
<tr>
<td>Biruh Tesfa Primary School</td>
<td>Kebele 03</td>
<td>SC_05</td>
<td>7</td>
<td>697.85</td>
</tr>
<tr>
<td>Ede Tibeb Primary School</td>
<td>Kebele 06</td>
<td>SC_06</td>
<td>11</td>
<td>1897.58</td>
</tr>
<tr>
<td>Tsehay Gibat Primary School</td>
<td>Kebele 07</td>
<td>SC_07</td>
<td>7</td>
<td>792.46</td>
</tr>
<tr>
<td>Chemoga Primary School</td>
<td>Kebele 07</td>
<td>SC_08</td>
<td>2</td>
<td>189.43</td>
</tr>
<tr>
<td>Abma Primary School</td>
<td>Kebele 03</td>
<td>SC_09</td>
<td>15</td>
<td>3285.45</td>
</tr>
<tr>
<td>Yene Primary School</td>
<td>Kebele 03</td>
<td>SC_10</td>
<td>8</td>
<td>1100.79</td>
</tr>
<tr>
<td>Endemata Primary School</td>
<td>Kebele 02</td>
<td>SC_11</td>
<td>10</td>
<td>1560.58</td>
</tr>
<tr>
<td>Deil BeTegil Primary School</td>
<td>Kebele 05</td>
<td>SC_13</td>
<td>13</td>
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</tr>
<tr>
<td>Hidase Primary School</td>
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<td>SC_14</td>
<td>5</td>
<td>657.93</td>
</tr>
<tr>
<td>Muaket Primary School</td>
<td>Kebele 05</td>
<td>SC_15</td>
<td>3</td>
<td>315.69</td>
</tr>
<tr>
<td>Debre Markos Preparatory School</td>
<td>Kebele 03</td>
<td>SC_16</td>
<td>19</td>
<td>4642.89</td>
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<td>Debre Markos Attekalay Secondary School</td>
<td>Kebele 04</td>
<td>SC_17</td>
<td>11</td>
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<tr>
<td>Menkeror Secondary School</td>
<td>Kebele 06</td>
<td>SC_18</td>
<td>14</td>
<td>1773.56</td>
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<tr>
<td>Ethio Japan Secondary &amp; Preparatory School</td>
<td>Kebele 03</td>
<td>SC_19</td>
<td>14</td>
<td>3841.54</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>18</strong></td>
<td><strong>32047.78</strong></td>
</tr>
</tbody>
</table>

Data and Softwares
Both primary and secondary data were used to assess the distribution and suitability analysis of selected infrastructures in case of Debre Markos Town, which were obtained from field survey, Debre Markos Town Land Management Team, Ethiopian Mapping Agency (EMA) and Google Earth. The data and materials used include satellite imagery, population data and GPS data.

Table 2 Types of Data and their characteristics

<table>
<thead>
<tr>
<th>No</th>
<th>Data Name</th>
<th>Data Source</th>
<th>Specification/format of Data</th>
<th>Data Type</th>
<th>Date of Data produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Quickbird Image</td>
<td>Google Earth</td>
<td>High resolution</td>
<td>Secondary</td>
<td>2016</td>
</tr>
<tr>
<td>2</td>
<td>Population Data</td>
<td>Debre Markos Municipality</td>
<td>Excel</td>
<td>Secondary</td>
<td>2013 projected data</td>
</tr>
<tr>
<td>4</td>
<td>Street Map Data</td>
<td>Debre Markos Municipality</td>
<td>shapefile</td>
<td>Secondary</td>
<td>2015</td>
</tr>
<tr>
<td>5</td>
<td>GPS data</td>
<td>Field Survey</td>
<td>GPS 60 Model</td>
<td>Primary</td>
<td>2016</td>
</tr>
<tr>
<td>7</td>
<td>Ethio GIS Data</td>
<td>EMA</td>
<td>Vector and raster</td>
<td>Secondary</td>
<td>20016</td>
</tr>
</tbody>
</table>

Table 3. Type of softwares and their functions

<table>
<thead>
<tr>
<th>Number</th>
<th>Software Name</th>
<th>Function of Softwares</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arc Map 10.4.1</td>
<td>To applied different geo-processing tools, Digitizing</td>
</tr>
<tr>
<td>2</td>
<td>DNRGarmin</td>
<td>Record or register the collected GPS data</td>
</tr>
<tr>
<td>3</td>
<td>Google Earth</td>
<td>Download and Crosschecking of data</td>
</tr>
</tbody>
</table>

Methodology
The study collected data by using GPS receiver, data conversion (raster to vector) data extraction, digitizing, query functions, join and relate function, geo-referencing data, spatial analysis, geo-statistics analysis, and different geo-processing tools. To produced suitability areas for new school site selection, the research applied suitability modelling automation. This modelling automation enabled and analysed that spatial data with attribute data by calibrating different geo-processing tools. The following diagram assessed, mapped and identified the suitability school site selection in Debre Markos Town. This includes detail geoprocessing tools and modelling automations. It summarized spatial and attribute data integration, classification, digitizing, overlay analysis, proximity analysis, symbology and spatial statistics analysis.
Criteria Used for Selecting the Best Location for the Facilities

The researcher used different criteria to assess the conformity and suitability of selected infrastructures in Debre Markos Town. These criteria are set by Amhara Regional State Education Beauru, and International scholars criterions. The researcher applied priority to assess the conformity and suitability of facilities by regional, national continental and global scale standards within respectively.

Schools: For this facility, the researcher uses Amhara National Regional State Education Bureau (ANRSEB), Talam&Ngigi, 2011 (worked in Kenya it is preferable and appropriate with to our country context and convenient for the researcher)

- Schools don’t far from above 2kms from the resident of the students (ANRSEB)
- Schools should be located at a minimum distance of 2Km from each other to minimize competition and encroaching in to each other’s catchment areas (Talam&Ngigi, 2011).
- Schools locate distance from road and streams distances greater than 450m are most suitable (Talam&Ngigi, 2011).
- Slope gradient school sites should be less than 15 degrees most suitable (Talam&Ngigi, 2011).

Results and Discussion

Schools distribution in Debre Markos Town

In this study, 18 public primary and secondary schools were selected. These schools located in different part of the towns but they weren’t distributed evenly. The following map indicates that the spatial distribution of public primary and secondary schools in Debre Markos Town.
Figure 2 Map of Primary and secondary Public schools in Debre Markos Town.

This indicate that in Kebele 03 more public schools are located compared with to other kebeles. In this kebele there are 6 schools or around 33 % while in kebele 01 there is no any public schools. In kebele 05, 4 schools, kebele 06, 2 schools kebele 07, 2 schools, kebele 02, 1 school and kebele 04, 3 schools are located. This condition will controversy with the principle of “fair and equity education for all” ministry of education. This will also discourage student who live far away the schools, especially, primary students and young students.

Schools Distribution Pattern

To analysed the spatial distribution of schools the study applied spatial statistical analysis tools. This enabled that to produce point density, mean location, central feature, median location, mean location and directional distribution of schools in Debre Mrakos Town. The following map summarized and illustrated these spatial statistics tools application and geographical distribution features of schools in Debre Markos Town.

Figure 3 Map of the distribution pattern characterises of schools in the town
The result revealed that the central location of these school is located kebele 04 between Debre Markos Attekalay Secondary School and Nigus Tekle Haimanot Primary School. The central feature location tool used to indicate the central location school with compared with to other schools. Median center also enabled that to the location that minimizes overall Euclidean distance to the features in a dataset. The median center of Debre Markos Town Public schools located around in the center of the city. Point density also calculated the density of point features around each output raster cell. Conceptually, a neighbourhood is defined around each raster cell center, and the number of points that fall within the neighbourhood is totalled and divided by the area of the neighbourhood.

This result classified and revealed that on three areas of the town high density of schools and the other schools are moderate and sparsely distributed along the town.

This study also tried to measure the geographical distribution of schools in Debre Markos Town by applied directional distribution and standard distance tools. These tools summarized the spatial characteristics of geographic features like central tendency, dispersion, and directional trends and measured the degree to which features are concentrated or dispersed around the geometric mean center respectively.

Schools distribution along with different infrastructures
A. Schools should be located at a minimum distance of 2Km from each other to minimize competition and encroaching in to each other’s catchment areas (Talam & Ngigi, 2011):

Based on this standard schools in Debre Markos town the distance between each other is various. To solve this problem, point distance tool on proximity tool set is a typical tool. This tool determines the distances from input point features to all points in the near features within a specified search radius. It creates a table with distances between two sets of points. If the default search radius is used, distances from all input points to all near points are calculated. The output table can be quite large. For example, on these 18 schools each school compute the distance between all other 17 schools, the result is 306 records in point distance table (18*17=306).

Table 4 the distance between schools

The lowest distance between each other is 126.223381 meters between Nigus Tekle Haimanot Primary School and Debre Markos Attekalay Secondary School. The second closet schools are also Debre Markos Preparatory School and Dehza Primary School around 362.657746 meters. In contrast to this, the maximum distance between is 7980.054463 meters between Chemoga Primary School and Yemeka Primary School. The second maximum distance between Biruh Tesfia Primary School and Chemoga Primary School around 7644.775556 meters. This indicated that there is high variation distance between schools. For instance, Chemoga Primary School is far away from all public schools.

The location of schools with the central place is Nigus Tekle Haimanot Primary School. This produced by using near analysis tool. This produced by using the central feature output and determine the centrality of schools. The most decentralise schools is Chemoga Primary School, it far way 5897.323345 meters away the central school.
Table 5 Most isolated schools from other schools

The distance between each school should be more than 2 kilometres. But table 4.3 show that around 16 schools are their nearest school is located less than two kilometres. The remaining Yemeka Primary School and Chemoga Primary School far away more than two kilometres from other schools.

Table 6 Schools which are far away more than 2 km each other

This indicates that around 89% of schools are located less than two kilometres distance between them and densely populated in the center of the town. The remaining two schools around 11% are located more than two kilometres far away any other schools.
B. Schools locate distance from road and streams distances greater than 450m are most suitable (Talam&Ngigi, 2011). Based on this principle the study assessed school’s proximity analysis regarding to road and rivers.

Figure 4 Map of Distribution of roads with to schools

This showed that all schools are located 450 meters’ buffer zone of roads. This will a good environment for students access their schools easily. But on some schools located side of highways. These highways have high traffic and traffic accidents. This will another negative impact on the security of students. To solve this problem the study used Generate Near Table, it calculated distances and other proximity information between features in one or more feature class or layer that between schools and highways. The result indicated that Debre Markos preparatory School, Tsehay Gibat Primary School and Biruh Tesfa Primary School are near to the highways and expose to traffic accidents for students. While Muaket Primary School, Hidase Primary School and Yemeka Primary School are far away the highways. These are safe for highways traffic accidents.

As table 4.4 Indicate that around 11 or 61% schools located with 450 meters distance of road facilities the remaining 7 s or 39% schools are located far more than 450 meters from road facilities. The following table illustrated the connectivity of schools with to highways in Debre Markos Town.
Table 7 Nearest schools for road facility

The other determinant the location of school’s streams and rivers. In Debre Markos there are around 3 main streams. Even though these rivers are seasonal streams on summer season they became flood. The following map revealed that around five schools are located in 450 meters buffer zone of rivers. This indicated that these schools are susceptible for summer flooding. These schools are Chemoga Primary School, Tsehay Gibat Primary School, Ede Tibeb Primary School, Endemata Primary School and Muaket Primary School.

Figure 5 Map of 450 meters Buffer zone of streams over schools
C. Slope gradient school sites should be less than 15 degrees most suitable (Talam&Ngigi, 2011): Based on this guideline steep slope are not suitable for schools rather flat areas or gentle slope are comfortable for schools. The result showed that the sites greater than 15 degrees are not suitable, Chemoga Primary School located in steep slope are that greater than 15 degrees’ slope inclination. The following map revealed that this slope value of school’s areas.

![Figure 6 Classification of slope over school’s distribution](image)

D. Schools should far from above 1000 meters from the markets (ANRSEB):
This guideline reduced the noise congestion of school areas, Markets are congestion of population and noise pollution. This has negative impacts on schools on their calm environment. There are four market areas in Debre Markos Town. On these market areas, there some schools around there.

![Table 8 The nearest distance between market and schools](image)
School, Biruh Tesfa Primary School, Ethio Japan Secondary & Preparatory School and Ede Tibeb Primary School. The above table 4.5 indicates their distance variation on ascending order.

Figure 7 Market areas 1000meters buffer Zone over schools

Figure 4.6 showed that the schools in the buffer zone of market centres, they expose for noise pollution. This negative impact of claim environment is not good for students and schools learning environment.

4.1.4 Identify the Suitable Areas of School Based on Guidelines

The identification of suitable areas of schools need an integration of different geo-processing tools. This indicate that an automation and suitability modelling for school site selection based on the above criteria.

Figure 8 Map of future suitable area for school sites

Figure 4.7 indicated that most of school concentrated on the center. But on the peripheral areas there is no
enough schools in the town. Future sites recommend that to build on the north and eastern isolated areas of the town. The identification of these future suitable areas for school sites are used modelling automation. It enabled that to consider the criteria and generate the areas which are full fill the criteria.

The following diagram showed that the integration of different tools. The model automation used buffering to zone the layers and erase to remove the layers which are out of the standards. Finally, it integrated all outputs by overlay analysis tool of intersect. It produced the areas which fulfilled the above criteria.

**Conclusion**

The study clearly indicated that 89% schools are located less than two kilometres far away than other schools and 11% are schools far away more than two kilometres than other schools. Around 11 or 61% schools located with 450 meters distance of road facilities the remaining 7 or 39% schools are located far more than 450 meters from road facilities.

Wuseta stream was the nearest river for Wuseta Primary school. Chemoga Primary School, Tsehay Gibat Primary School, Ede Tibeb Primary School, Endemata Primary School and Muaket Primary School are the other nearest rivers in ascending order distance from the river.

Seven or 39% schools are located with 1000 meters buffer zone from market centres 11 or 61% schools are located far 1 kilo meter from the market centres. The south-eastern edge areas were the steep slope area and not comfortable for new site selection. North and East edge part of the town is the suitable areas for new school site building areas.

**Recommendation**

Debre Markos Town Land management team and municipality, they should adopt and implement GIS technology for their day to day tasks. All areas of the town should register and implement good land management and administration system by using geo-spatial technologies. Debre Markos Town Land management team should always identify the suitable areas by using national and international standards and criteria.

In general, GIS technology and standards enable to enhance proper land management system in the town and effective and efficient implementation of school and other urban public facilities distribution in the town.
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