Application of Geographic Information Systems for Government School Sites Selection

by

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DECLARATION

The work described in this thesis was carried out by me under the supervision of Associate Professor Mrs. T.M.S.P.K Thennakoon, Department of Geography, University of Sri Jayewardenepura and Mr. H.H. Leelananda, Teaching Faculty Member of the M.Sc. Degree in GIS and Remote Sensing, Director Land Use Planning, Mahaweli Authority of Sri Lanka and confirm that this has not been submitted in whole or in part to any university or any other institution for another Degree or Diploma.

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APPROVAL OF THE SUPERVISORS

We certify that the above statement made by the candidate is true and that this thesis is suitable for submission to the University for the purpose of evaluation.

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LIST OF ABBREVIATIONS

AHP - Analytical Hierarchy Process
DESL - Department of Education Sri Lanka
DSD - Divisional Secretariat Division
ESRI - Environmental Systems Research Institute
GIS - Geographic Information System
GND - Grama Niladhari Division
HSEB - Higher Secondary Education Board
IT - Information Technology
MCDA - Multi Criteria Decision Analysis
MCDM - Multi Criteria Decision Making
MESL - Ministry of Education Sri Lanka
RS - Remote Sensing

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ABSTRACT

The application of GIS has become more popular among the policy planners and decision makers of the education sector in many countries. GIS application in the education sector has several advantages such as effective education planning and more particularly in the estimation of numbers and identification of site for the location of new schools. In Sri Lanka today defining the school catchment area and determining the shortest and safest school route is one of the problems facing education authorities at present.

The purpose of this study was to develop a public school site selection model using Graphical Information Systems (GIS) integrated new approach. The study has used GIS based MCDA technology to improve the accuracy of school site selection model. The model appeals to school development planners as well as to the education decision makers and higher authorities of the school education system in both local and central governments who seeking the optimum selection of the site of a public school facility in the country of their competence.

The first step of the study focuses to evaluate the existing school system of the country and also the study area. It was most important to identify and analyze the current situation of the resource allocation to schools and the school education planning system in the area. Secondly, the collected data was analyzed in order to identify of the potential school sites for developing as national level based on geospatial technology using the ArcGIS Software tools.

Next, developed model was applied to determine the suitable school sites for development in the study area. As a result, it was possible to identify most suitable two sites for locating principal schools for the area. According to the evaluation of the current development project locations, there is considerable evidence that because of
poor geographical accessibility, current school development project does not reach the equitable quality education access to the population in the study area.

This study reveals the consideration factors of education system for equality resource allocation process to optimum and sustainable development within the society. Hence, this model can be used for any spatially related resource allocation applications by changing parameters based on concerning subject. The study is very opportune and timely as GIS application used for education sector development is very rare in Sri Lanka. Therefore, the present research would be an offer for the use of GIS application in the education sector in Sri Lanka.

**Key Words:** GIS, Education, Multi Criteria Decision Analysis, MCDM,
CHAPTER 1

INTRODUCTION

1.1 Background

The education structure is the most important factor of the development process in any country. In developing countries, the correlation between people’s level of educational achievement, individual earnings, employment opportunities in the job market and agricultural productivity are positively significant. Therefore, education is highly correlated with not only the country’s development but also with an individual development, living condition of the people and finally it affects with the socio economic development of the society. Education affects the developments through various dimensions of cognitive competence, literacy (reading and writing ability) numeric competence, modernity and problem solving behaviors (Lockheed and Verspor, 1991). Therefore education is a very important factor for development of a country in many dimensions. Hence, it must be used with proper planning, the use of advanced technologies and improved facilities for educational planning and decision making.

On the other hand, the population of the developing countries has been increasing year by year while population density increases due to the land area in a country being limited. This situation is creating a huge challenge to policy planners in various government departments. The main problem in departments of public services is that they have limited facilities, capacity and resources being shared equally among a large population.

The demographic explosion in Sri Lanka also has created a tremendous pressure on resources and public services accessibility. The population of Sri Lanka was 14,846,800 in 1981, and it has increased up to 20,263,700 in 2012 (Central Bank of Sri Lanka, 2013). According to the national policy of the government, providing equitable entrance for education is a fundamental policy of the education system in Sri Lanka. In order to ensure this policy, during past decades, a variety of school education development Projects have been implemented. Some of the main evidences are the free education
policy in 1945, establishment of central colleges, implementation of education school textbooks, uniforms and mid-morning meals. As a result of these projects the participation in education has increased substantially.

Since independence, all the governments in Sri Lanka followed these policies, and as a result of the significant government expenditure on education, the student enrolment rate and literacy rate have increased. Due to the overall primary education development of the country, demand for the quality higher education facilities also has rapidly increased all over the country. In this case, the current education system of Sri Lanka faces a lot of problems such as determination of school catchment area, school facilities distribution, student travel time, transportation problem and more. At present those schools in the rural area are being closed down while some urban schools attract a large number of students. This has resulted to create many problems in the school education system which has negatively affected education quality and development. The number of schools with less than 100 students has increased very fast, it was reported as 2,973 in 2009 and it increased up to 3189 in year 2012. On the other end, the number of schools with more than 3,000 students has been increased to 106 (Ministry of Education Sri Lanka, 2012b) (MESL).

Therefore, any investment for the education system needs careful planning and decisions based on the national education policies. Such attempts strongly will assist the improved educational infrastructure facilities. In terms of learning achievements, Education For All (EFA) movement has been continuously highlighting the need for addressing disparities in terms of equity and quality of the education system (UNESCO, 1990; MESL, 2011; MESL, 2012a).

Hence, educational investment should be clearly focused on to minimize disparities in the national education system while preparing students to meet the labor market requirements and to improve efficiency, productivity and their own earnings. In this case, there is a high need and advantage of greater emphasis is given to initiate appropriate programs at school level specifically targeting students (MESL, 2010).
The historical result of proper and improper school site selection methods have been explored by the MESL (2010) in a special concept paper for 1000 school development plan and it could be described as follows:

“When the 54 Central Colleges were established, Dr. C.W.W Kannangara directed the officers to follow accurate school mapping exercise to select the locations. Most of such Central Colleges are today functioning as centers to deliver a better service to the surrounding primary schools. Nonetheless, we have to admit that certain previous school development programs which did not follow proper mapping exercises (‘Navodya’, ‘Isuru’ schools) have not been able to reach up to the desired objectives” (MESL, 2010, p. 5).

The phenomenon is similar in the study area that has rapid population increment and is subjected to large scale residential land sales and housing projects throughout the area. At the same time, many infrastructure and other development projects have been started, such as an economic center at Godagama, large scale stadium and sport complex at Diyagama, three universities in Pitipana and Diyagama areas, nano technology park, wide road network with highway, electricity and drinking water supply projects and land parcels ownership project can be shown as examples. On account of this, Homagama and the surrounding area have become a highly preference residential area. Due to this situation student population in the area has also increased during the past few years and the school system is struggling to provide the educational needs of the community. Therefore, existing school system was unable to fulfill the demands of the population. On the other hand, there is no improved government school network which is implemented at national level.

As a result, the Homagama area has only one school with science, arts and commerce subject streams, which is classified as a type 1AB school by the Department of Education (MESL, 2012b). Further, some regional schools have not been popular because of lower population density, poor quality road network and lack of facilities. Therefore parents make many attempts to admit their children to the few schools with good facilities, resulting in tremendous competition. In this context, new schools have to be developed in correct locations to satisfy this growing demand.
Hence, to overcome these challenges more advanced technologies must be used to assist the proper planning and decision making in the school development process. Information Technology (IT) is developing very rapidly in the world today and its width in scope and proper use and integration will make problem-solving easier. There are several information technology applications to assist in solving problems in the education planning and administration sector.

Geographic Information System (GIS) is a computer based database system that enables analysis with spatial related data in most application fields as an advanced and technologically elegant tool. GIS is the most suitable technology to solve this type of problem because it can combine attribute data with spatial data. The GIS database can provide a comprehensive frame work and organization of spatial and non-spatial data and become a powerful tool to help planning and decision making activities.

The GIS is a computer based information system that enables capturing, storing, manipulation, analyzing, modeling, retrieval, and presentation of geographically significant reference data. GIS is a powerful tool for data presentation, visualization and identification of incident patterns. Also it is very useful for decision making processes in many subject areas. Therefore application of the GIS as a decision making tool has been increased to help decision making process all over the world today. Problems of infrastructure development and equality in resource allocation for the community are the main development difficulties in Sri Lanka. Hence, geographic thinking is important for school administration and facility allocation.

Therefore, in order to address these problems the Geographic Information System (GIS) could be applied to make proper decisions for developing the existing school system. As a new approach the GIS based Multiple Criteria Decision Making (MCDM) method was used to identify suitable schools to be developed as principal schools. The use of GIS and MCDM, suitability assessment taking into account not only spatially related data but also analytical planning (Mendoza, 2000).
1.2 Research Problem

Providing equitable access to the quality education facility is the primary problem of the education system faced in Sri Lanka today. Student population is growing fast according to the past statistics in Sri Lanka. The student population was 2,625,291 in 1972, 51, and 69,000, in 2001 and it has increased up to 5,73,8000 in 2011 (Central Bank of Sri Lanka, 2013) (CBSL). According to the statistical data not only student population, but also the total population also has increased rapidly. Due to this situation determination of new residential areas and land use changes need to be identified properly in any regional area of the country. With the introduction of the universal free education policy in 1945 and significant government expenditure on education Sri Lanka has achieved remarkable levels of literacy. The school enrolment rate is also high in Sri Lanka when compared to many other countries in the world. The overall literacy rate for the country was 57.8% in 1946 (Panditaratne and Selvanayagam, 1973) and it was reported as 92% in 2012 (CBSL, 2012).

While the literacy rate has increased in the country, the demand for quality and high education standards have also increased rapidly in both urban and rural areas. When considering the current crises of the school education system in Sri Lanka a positive correlation can be identified between literacy rate and demand for high quality school education facilities.

But the problem arising today is how high quality education facilities could be shared equally between urban and rural areas at a micro level. The present ground reality is that the highest numbers of principal schools are limited to urban areas or sub urban areas in the country. According to the distribution of school by type 74% of schools are primary or secondary schools in 2004 and has increased up to 92% in 2012. And also there are only 8% of national level schools which are funded and controlled by government (ME SL, 2004; MESL, 2012b).

According to the findings of the Tilakaratna (2009) most of the type 1AB schools were distributed in urban areas of Colombo, Gampaha, Galle, Jaffna, Kaluthara and Kandy districts. However this situation also changes among the regional areas within the same district. The selected study area consist of 81 Grama Niladhari Divisions (GND), but it
has only one school with all A/L subject streams and it is also situated at the main town. The result of this common situation of the country today was created with regard to inappropriate distribution of facilities among the schools system as explained by Tilakaratna, (2009);

- Most of type 1AB schools are limited to 7 districts.
- Distribution of Schools with A/L classes is high in few districts.
- Significant disparities in terms of physical and human resources both across and within district.
- Micro level analysis, visible disparities among urban, rural and remote schools.
- Over 75% of schools in the district of North & East, Nuwara Eliya, Anuradhapura, Matale, Kegalle are without a permanent library and majority of these districts, over 60% of schools do not exist even temporary library or reading room.
- Disparities with regard to student graduate teacher ratio and teachers for English language in many districts.
- Disparities record in computer facility and sport facility in many districts.

Identifying schools for development, establishing student intake boundaries and allocation of resources for schools are not being maintained in a systematic way in Sri Lanka. Some policies are based on unsystematic methods due to unavailability of qualitative and geographical spatial referred data. The clearest example is the student intake policy for grade one. In this case, distance from school to candidate’s house is the main criterion. But it is not applied to calculate road distance between school and the candidate’s house because of the unemployed of advance technology like GIS with potential for calculating distance to any point in the surrounding area. Therefore, it is necessary to consider air distance to select the students by drawing a circle around the school on the area of paper map. Since this type of inappropriate application of the criterion is used, many socio economic matters in society are not properly handled.

The main difficulty is the insufficiency of schools with quality facilities in an area where the demand for good education is very high. Most of the schools do not meet the
basic facilities for the students. As well as Principal Schools with many facilities are have distributed in a few urban and sub urban areas of the country as at present in above. Due to this situation the demand for the urban and sub urban schools has rapidly increased yearly and as a result of this, many village schools have been closing down today in Sri Lanka (Tilakaratna, 2009; MESL, 2010).

Since this a common situation for all districts of the country, many governments have introduced a variety of school facility improvement project in the past decades. Some of them are Pokuru Pasal, Navodya Pasal, National schools, Provincial schools and Mahindodaya pasal. But all those projects had not able to overcome the above challenges in the school education system. The main reason for the failure/unproductive of these projects has been identified as poor site selection method for the development. Therefore lack of suitable advanced site selection and mapping technology is the main problem in the education system of today.

Further, when considering the education facilities distribution pattern of study is in a very poor situation, because it is limited to only one type IAB school which offers arts, commerce and science subject streams. With this background, the high demand for the few facility schools has increased year by year. Due to this situation many socio economic problems have been created in the society of the area. Therefore, identification of existing schools to be developed as national level schools is the first key factor and it is directly related to the demanding population. Also this condition is a common issue throughout Sri Lanka. Therefore, making good preparations and analysis on the parameters of site selection are absolutely necessary. Another main problem with school location is that it may be in an unsuitable location due to environmental or land use factors. Many schools have been located in places very near to the major towns that are highly polluted in many ways. Air pollution, crime, and accident rate are very high within the commercial areas same as in other countries in Sri Lanka today.

The existing structure of the education system in Sri Lanka has two main sectors which are school education and university education. There are more than 40, 27,000 students in the 9,829 government schools all over the country (MESL, 2012b). There are some valuable statistical data regarding schools under the Department of Education of the Ministry of Education. The main items are name of the School, address, district and
educational zone, type of School, number of students, number of teachers, land size and sanitary facilities.

However, there is no facility to be accessed remotely, therefore data cannot be updated or used from regional locations anywhere in the country. This data is used in manual calculations and explanations but it is not linked with geospatially. The Department of Surveys has located schools as points on their topographic sheets, which are in hardcopy format but not in digital format. Since these maps had not provided geospatial reference and attribute data they cannot be directly used with GIS software tools.

Another problem is lack of people with knowledge of GIS in the education planning sector. Therefore, it is a basic requirement that skilled people in information technology, geography and GIS subject areas be recruited. In addition due to the unavailability of digital data, the educational planning sector has faced many difficulties in delays accuracy issues on school mapping, planning and decision making activities have arisen. On the other hand, development needs of schools have been increasing rapidly. Therefore, school information management, student intake methods, resource allocation and new site selection for development are the most challenging and critical problem areas of the school education planning system today.

In this context, education planning in Sri Lanka needs serious attention. The planning difficulties faced by the education authorities are increasing and are hard and cannot be addressed by means of traditional methods alone. In this case there is a timely need to use more advanced systematic technological methods for school planning and decision making process. It seems that the time is ripe for the introduction and development of new methods which could enable a more proactive and productive approach. The school facility management based on GIS technology will help to determine future needs, potential school sites and locations for development. Also it helps to identify resource allocation disparities clearly in an area and where to target new education improvement funds to achieve the sustainable development needs.
1.3 Significance of the Study

The significance of this study can be described under two subjective categories in the following manner.

- Significance of the study Global, National and Regional levels
- Significance for the socio economic development of the country

1.3.1 Significance of Global, National and Regional Levels

Planning of education facility to access equally for all is highly intermixed with geographical spatial scope. But Education authorities are not using geographical thinking to solve the problems it is facing in the education sector. The vast majority of techniques used in educational planning are outdated and even those drawn from geography are rendered virtually obsolete by the recent reforms.

![GIS Applications for Schools](image-url)

**Figure 1.1:** GIS Applications for Schools  
**Source:** ESRI, 2009a
Possibilities of GIS to provide support for the education planning and mapping as a decision support system is explained by the Environmental Systems Research Institute (ESRI) which is the leading institute in GIS software displayed by Figure 1:1. This evidence shows the applicable and importance of GIS analysis for educational planning.

The trend using GIS and school mapping to assist decision making for education authorities in the world is becoming very important for planning purposes and its implementation in many leading and developing counties in the world (Al-Hanbali, 2003; Banskota, 2009; Rice et al 2001; Eray, 2013). The trend of using GIS for school mapping to support decision making is becoming more important due to many presentation of research studies done by leading countries. They have presented the significance of these researches with practical contribution of the integrating GIS with education planning for decision making.

Eray (2013) has presented an application of school location analysis using GIS technology in Old Tbilisi district. He has collected geo-reference locations of all private and public schools as well as attributes data on schools and has created a geo-database on the collected data. As a result, locations are output as geographic features with their attributes, which can be used for mapping or spatial analysis. By this database another useful technique created was a buffer zone to capture the coverage area of a particular school. This analysis is used to determine the correct school locations based on residence zone, and school related problems. This was used to detect problems between school and other buildings, distance to petrol stations or other hazard locations and also to identify demographic situation in the school coverage area to assist the current and future developments.

Liddle (2012) has applied GIS technology to find the proper locations for new school buildings to address the insufficient public school needs in Durham city of North Carolina in America. In this study the researcher has used GIS integrated Multi Criteria Decision Making (MCDM) analytical method to identify suitable locations for public high schools. According to this method, he has considered four types of criteria which are environmental, safety and accessibility and also many sub criteria under the main criteria. Advanced significance of GIS based MCDM is possibility of study nature in many effected factors to the problem. Therefore, education planers could select proper
potential school site and it will be added more contribution to the sustainable developments of education sector in a country.

According to many researchers, using GIS and school mapping to support decision making is more significant for planning purpose (Al-Hanbali, 2003; Banskota, 2009). GIS based application experiences are very higher in Nepal. The Higher Secondary Education Board (HSEB) in Nepal formed 1990 has been started new formation with new technology in the overall education structure of the country.

“Various Organizations in Nepal have already been applying GIS in various fields like natural resource management, watershed management, urban planning and management, disaster management etc. In such situation HSEB began its initiative in implementing and using GIS as one of the analysis tool for educational database management and support decision making. The Nepal government has planned to open-up higher secondary schools in the area of need and in location where there is potential for this, school mapping exercise with focus on identifying existing secondary schools with potential for upgrading and the spatial identification of existing higher secondary schools is important step in order to provide quantities and qualitative expansion of higher secondary in the country.” (Banskota, 2009, p.2)

Education systems of the developing countries face many problems such as determination of school catchment area, equity facility distribution, student transportation and site selection. Yildrim and Aydinoglu (2007) have implemented an interactive e-enrollment model to solve the problems in the determination of school redistricting and school bus routes. In this study they have explained matters arising in the determination of school catchment area manually. If the school catchment area is not identified accurately a student’s travel time might be high. Due to this traveling cost, vehicle traffic and many other related problems will be created. This problem is very common in Sri Lanka. Creating the school catchment area using GIS is the best solution because GIS is capable of providing a best solution considering all the factors related to that ground reality.
Location Allocation Analysis (LAA) is one of the most useful GIS tools that can be used to locate public facilities in order to provide the equity distribution among the population properly. Despina et al. (2006) have undertaken a study to achieve the above possibility in Athens, Greece. The aim was ascertainingment of the insufficient social service of the cultural center’s current location and detection of new optimum site for the centers. They have done this assessment of the service to the citizens and the investigation for an optimum location of the center in the area of the city based on public facility location allocation theory (Koshako, 1983; Richard et al., 1990) and they have been able to reach success of the objective.

Providing facility for public transport demand is a main problem in most developing countries as same as in Sri Lanka. Transport issues have increased due to increase in population in most cities of India and they have created a number of problems in school bus operating system. Therefore, to address this, GIS based school transport management system has been submitted for the Sujatha High School, including bus stop allocation, fast and shortest route for the buses, automatic vehicle locations and with enhanced transport security system (Nayati, 2008).

Possibility and impotency of GIS application to solve this type of problem is mentioned clearly by the following indication.

“GIS based School bus routing and scheduling System was developed for routing of school bus from school to student locations and vice versa. In this system the most important issues were the fastest path, shortest path, bus allocation, identifying the vehicle location and storing the student’s location information in the database.” (Nayati, 2008, p. 67)

Transport is one of the prime applications of GIS. It can be very helpful in making school routes and in other school transportation services. Many schools around the world are using GIS and finding it very easy and helpful to operate. The great use of software package with an element of GIS technology is routing, scheduling, tracking and navigation.
The GIS application used for spatial problem solving has not a long history in Sri Lanka and some studies have been conducted for limited subject areas such as land use mapping, natural hazards, water resources analysis and health cares. Following information and evidence regarding usage of GIS in Sir Lanka will be providing a clear picture about the current situation.

Most of the GIS integrated studies are limited to the land and management field. Dahdouh-Guebas et al. (2002) have conducted a study to investigate the mangrove area in the Pambala Chilaw Lagoon complex in Sri Lanka. A land use map was drawn in a geographical information system of the study area using air borne remote sensing. Suthakar and Bui (2008) presented a paper to measure and spatially characterize land use cover changes in the Jaffna Peninsula, Northern Sri Lanka over the two decades from 1984 to 2004 during the period of armed conflict between the government of Sri Lanka and the terrorist of Tamil Eelam, using multi temporal satellite data, over this period. Weerakoon (2002) has demonstrated an integration of GIS based suitability analysis and multi criteria evaluation for urban land use planning, contribution from the Analytic Hierarchy Process with application at fuzzy set theory in GIS for urban land use planning. De Silva et al. (2001) conducted a GIS study to observe the land use pattern of the catchment area of nine reservoirs in Sri Lanka, for which detailed fishery data, viz. yield, fishing intensity, landing size of major constituent species were presented.

Variety of the GIS based decision support analysis has been introduced in health and environmental sector in many countries as well as in Sri Lanka. Savigny and Wijeyaratne (1995) added their contribution to this sector applying GIS for review Health and the Environmental matters. The International Water Management Institute (IWMI) launched a project of GIS-based malaria risk mapping in Sri Lanka, to investigate whether this tool could be used for epidemic forecasting and for the planning of malaria control activities (Klinkenberg, et al. 2004). This study presents results for the Uda Walawe region in Southern Sri Lanka, an irrigated agricultural area where malaria cases were mapped at the smallest administrative level for each month over a 10 year period.
Dahdouh-Guebas, et al. (2005a) have conducted a research about transitions in ancient inland freshwater resource management in Sri Lanka affecting biota and human populations in and around coastal lagoons in Sri Lanka based on Anuradhapura UNESCO World Heritage. Researchers, Tripathi and Bhattarya (2004) have implemented a system integrating indigenous knowledge and GIS for participatory natural resource management of the country. Another study by Bastiaanssen, and Chandrapala (2003) describes a new procedure for hydrological data collection and assessment of agricultural and environmental water use using public domain satellite data. In this study, variability of the annual water balance for Sri Lanka is estimated using observed rainfall and remotely sensed actual evaporation rates at a 1 km grid resolution.

GIS and Remote Sensing (RS) based model has been developed by Udayakumara, et al. (2010) in order to assess soil erosion in a critical watershed and recognize its determinants at the Samanalawewa watershed area which contains one of the main hydropower generating reservoirs in Sri Lanka. Also Wijesekera and Samarakoon (2001) offered a research project regarding extraction of parameters and modeling soil erosion using GIS in a grid environment.

Another wide range of GIS integrated researches were presented for coastal natural hazards and earth stem sciences, in Sri Lanka, Ingram et al. (2006) have engaged to identify the Post-disaster recovery dilemmas challenges and proposed a system to balance short term and long term needs for vulnerability reduction based on the tsunami hazard in 26 December 2004. While Garcin et al. (2008) presented a GIS integrated approach for coastal hazards and risks in Sri Lanka.

"The models use the data from the GIS and in turn, the GIS uses the results from models making it possible to assess numerical quantities, maps and other information useful for communication with decision makers and the general public. The methodology used produces maps of different hazard levels which permit, for example, to define the most suitable areas for rebuilding. In built-up areas that were not destroyed by the tsunami, this approach can also give the level of hazard to which they are subjected. This will help define the risks incurred by the people and properties in these areas
but also to define standards for the construction of new buildings or for the upgrading of existing structures in order to reduce their vulnerability” (Garcin et al., 2008, p. 585-586).

In this context, almost all the studies were limited to land, water, health and natural hazard and environmental subjects. It was not found a single research project integrating GIS and education planning and this display the wide gap of the GIS studies in Sri Lanka. The significance of this study as a research project is quite evident from the above facts.

1.3.2 Importance to Socio Economic Development of the Country

Performance of schools measured by public examinations and national assessment results in many educational zones is low. Lack of availability of a better school network with quality primary and secondary schools may contribute to this unsatisfactory situation. It is a well-known fact that many parents are willing to enroll their children in popular schools in the urban areas and the demand for such schools for exceeds the supply. The enlarged demand for urban and sub urban schools have directly resulted in increasing the number of smaller schools and gradual closing down of such schools in the rural peripheral areas.

However, as a result of the lack of quality schools in living areas people have faced many socio economic problems. According to the well known present social experience in Sri Lanka, parents began to collect evidence to enroll their children in popular principal schools on child birth. In this case, people usually try to make many illegal documents for the school enrollment process. This creates a number of issues connected to quality of education. Hence, the Government of Sri Lanka should turn into solutions which address social demand for equity and quality of education while assuring efficient investment of available resources by using advanced suitable technology. In this context, it is essential to identify schools for the development programs based on a careful planning and mapping techniques like this study.

The GIS application used for education sectors is still very rare in Sri Lanka today due to lack of GIS based application development. There is one fully GIS based research on
the subject of school educational disparities in Sri Lanka (Tilakaratna, 2009). This study has identified school educational disparities in many dimensions at country level as well as at micro level. According to this study, 37% schools are primary or secondary schools and only 6% have A/L science classes, in the entire country (Tilakaratna, 2009). The high facility schools are distributed in highly urbanized areas. On the other hand, rural or semi urban areas do not have better school distribution in relation to the demand. The reason for most of these problems is weak decision making on facility distribution without studying the ground reality. Therefore, geographical thinking is strongly applied due to all school related problems being spatial. Hence, this study will assist in solving educational disparities in the study area.

According to above evidences, the GIS have proven to be an extremely effective and efficient tool to solve the many problems in education sector. But in Sri Lanka, GIS usage is very low in education and other sectors except land and environmental hazard areas. In this research, it could not be found any type GIS application use for the decision support in school education sector. However, one school administrator office have founded in Ministry of Education that use GIS simply to produce a paper map to identify the selected schools locations for 1000 school project.

Therefore, this study has many advantages to be addressed to a greater extent by improving schools with quality and sufficient physical infrastructure and enriched teaching and learning processes. Hence this important exercise could be the lead project of the school education planning sector for the next years. Finally this study will provide a better path for education planners to take better decisions to solve the critical educational problems in the country using GIS Technology. This will be one of the initial steps to providing a fully integrated GIS based School Decision Support System for the school education sector in Sri Lanka.
1.4 Objectives

The purpose of this study is to develop a model to assess the suitability of school sites for development integrating Geographic Information System (GIS) and to apply the model for development of the existing school system in the Homagama Divisional Secretariat Division (DSD). This new approach is based on GIS integrated multi-criteria analysis with distance analysis, and overlay analysis to meet the objectives.

- **Main Objective**
  - Develop a GIS technology based model to identify most suitable existing schools to locate the potential principal schools.

- **Specific Objectives**
  - Identify and examine the present site selections to locate the principal schools of the study area.
  - Develop a geospatial school data layer of the study area to assist to the future studies and planning purpose.

1.5 Limitations of the Study

Unavailability of updated digital data of better scale is a very effective limitation of this study. The digital data used in this study are 1:50000 layers is limited ground information. Therefore it has more advantages of use 1:10000 or other relevant scale data layers to meet the high accuracy result.

The difficulty in data collecting from related institutions is another restraint faced in this study. Many officers are not fair happy to give data and information in details and it may be due to mainly unavailable collected compete data and their busy time schedules.

The other major limitation faced was there are no precedents to follow as similar research has not been undertaken regarding education system in Sri Lanka. All the evaluable past studies from foreign countries hence, it is difficult to study needs and criteria related to the country. As well as has many advantages of study previous
experiences with cultural, socio economical and geographical background since this scenario is strongly community related.

Limited time is other major limitation of this study because to perform a better literature review and for the data collection should have spend more time for this type of study. Because of success of the research mainly depend on these two activities. But it was impossible to dedicate much time for these two activities due to limited time for the research.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

School mapping is the art and science of creating geospatial databases with the use of demographic, educational, social and economic information for schools and educational system to support educational planners and decision makers (Hanbali, 2004). According to many empirical studies, using GIS for school mapping to assist decision making in school education departments is becoming very important in the world. Efficient planning for the civic services faced challenges with the growth of population (Zhu et al., 2005). Many studies have been undertaken around the world to assess the spatial distribution of public services and their accessibility to the community. Developing geospatial databases and using GIS is becoming a requirement for funding agencies to approve loans or grants such as World Bank, US Aid and Department for International Development (DFID). An example is the workshop conducted for DFID funds (Rice et al., 2001).

Due to the advantage of GIS application in school mapping and decision making activities, practical experiences and research can be found in many subject areas. Since this thesis is a combination of school resource allocation and GIS application, this literature review is spread in four areas which are of importance to education and status of the education in Sri Lanka., GIS for better education planning and decision making, school site selection policies and criteria, GIS integrated Multi Criteria Decision Analysis (MCDA) experiences and also especially multi criteria analysis for school related problem solving which is use in this study.
2.2 Importance of Education and Education Status of Sri Lanka

2.2.1 Education for Source of Human Capital

The correlation between people’s level of education and the possibility of individual earnings, employment opportunities in the job market and agricultural production is positively significant. Also personal Education level is highly correlated with not only their individual personal development but also the development of the country. Finally this is the link with their living conditions and socio-economic development of the society (Lockheed and Verspor, 1991). Therefore education is a very important factor in development in many dimensions and it must be used with proper planning and investment.

This important idea has been discussed in many research works throughout the world. For example; returns on investment in education, in the modern human capital sense of the term, have been estimated since the late 1950s. In the 40 plus year history of estimates of returns on investment in education, there have been several reviews of the empirical results in attempts to establish patterns (Psacharopoulos and Patrinos, 1994).

Every person hopes for a better life. Hence, to reach this goal learning is the path according to the above evidence. Successive Sri Lankan governments have made investment in education a priority. The Sri Lanka government has invested expenditure on education at around four percent of GDP in the past years (Tilakaratna, 2006).

Another significant learning outcome is peace and social harmony; learning to live together is one of the basic aims of investment in the education (Ministry of Education Sri Lanka (MESL), 2012a). Sri Lanka is a multi-cultural society and after experiencing the trauma of an ethnic conflict, peace and harmony is an essential outcome of education. Further, environmental education and health education are also important as well as communication and technology for all. This information is presenting the way of manage peoples’ living condition by education.

“The life skills approach has expanded including the acquisition of knowledge, values, attitudes and skills through the Four Pillars of Learning:
Moving towards the goal of sustainable development requires primary changes in human attitudes and behaviors. Progress in this direction is critically dependent on education and public awareness (UNESCO, 1990). Therefore, to attain sustainable development better planning and investment in education are absolutely essential. Then indeed, education will reshape the world of tomorrow.

There is a strong and positive correlation between education and living conditions of the society. This means people’s socio economic level depends on the education investment, educational resource availability and equal education opportunity in the country. This is one of the main challenges in many developing countries today.

2.2.2 Education Disparities in Sri Lanka

Since the universal free education policy was introduced in 1944, literacy rates and educational achievement levels have steadily increased in Sri Lanka. At present the youth literacy rate stands at 97%. The government gives high priority to improving the national education system and access to education, but there are great disparities in the distribution of educational facilities at micro level throughout the country (Tilakaratna, 2004; Tilakaratna, 2006). Therefore, when discussing the quality of the education in Sri Lanka, the existence of regional disparities in education and the slowing down of further increases in literacy and enrolment rates at the national level have to be taken into account.

According to Tables 2.1 and 2.2 in the information report of the Department of Education there are only 3% of national or principal schools, while 72% of schools are primary or secondary schools. About 20% have G.C.E Advanced Level classes while only 8% have G.C.E science classes out of all schools in the country (MESL, 2012b).
Table 2.1: Number of National and Provincial Schools in Sri Lanka

<table>
<thead>
<tr>
<th>National/Provincial</th>
<th>Schools</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percentage (%)</td>
</tr>
<tr>
<td>National schools</td>
<td>342</td>
<td>3</td>
</tr>
<tr>
<td>Provincial schools</td>
<td>9,563</td>
<td>97</td>
</tr>
<tr>
<td>Total</td>
<td>9,905</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Ministry of Education Sri Lanka (2012)

In addition, according to the student’s statistics given by the ministry of education, 8929 (90 %) schools have less than 1000 students. Another important aspect shown by statistics is the number of teachers in schools. In overall 2958 schools have less than 10 teachers as a percentage it is 30%.

Table 2.2: Number of Students and Student-Teacher Ratio by Schools Type

<table>
<thead>
<tr>
<th>School Type</th>
<th>Number of Schools</th>
<th>Percentage (%)</th>
<th>Number of Students</th>
<th>Percentage (%)</th>
<th>Student-Teacher ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1AB</td>
<td>753</td>
<td>8</td>
<td>1,426,358</td>
<td>36</td>
<td>22:1</td>
</tr>
<tr>
<td>1C</td>
<td>2013</td>
<td>20</td>
<td>1,250,115</td>
<td>31</td>
<td>18:1</td>
</tr>
<tr>
<td>Type 2</td>
<td>3869</td>
<td>39</td>
<td>876,409</td>
<td>22</td>
<td>13:1</td>
</tr>
<tr>
<td>Type 3</td>
<td>3270</td>
<td>33</td>
<td>451,204</td>
<td>11</td>
<td>18:1</td>
</tr>
<tr>
<td>Total</td>
<td>9905</td>
<td>100</td>
<td>4,004,086</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Source: Ministry of Education Sri Lanka (2012)
Regional disparities can be identified in many areas: in Nuwara Eliya, Vavuniya, and Batticaloa over 50% of schools are Type 3, but in Colombo it is less than 15%. Schools with A/L classes in the above areas are less than 20 percent. The number of schools in a district may depend on many factors such as population and land area. It varies from less than 100 in Mannar and Kilinochchi to over 600 in Kurunegala and Kandy. But, considerable disparities exist with regard to the distribution of Type 1AB schools. According to the educational statistics over 75% of the schools in the districts of North and East, Nuwara Eliya, Anuradhapura, Matale, and Kegalle, do not have a permanent library. In the majority of these districts over 60% of schools do not even have a temporary library or reading room. The district of North and East reported the highest percentage of schools without any lab or science room. Computer facilities are very limited in the districts of Kilinochchi, Mullativu, Monaragala, Nuwara Eliya Anuradhapura and Polonnaruwa (Tilakaratna, 2009).

Therefore, achieving the concept of sustainable development requires better planning and investment in Sri Lanka education sector.

2.3 GIS for Better Educational Planning and Decision Making

GIS is changing the way spatial data is analyzed and representations are made and finally decisions taken in many subjects such as anthropology, geology, environmental science, forestry and business. Today education related planning and analyzing based on GIS are taking the benefit of GIS. Determining school boundaries is a difficult task in many countries. There are many variables and factors to be considered when deciding the intake boundary line. School administrators are now purchasing and developing GIS systems to improve school boundary planning and resource sharing. According to the Environmental Systems Research Institute (ESRI) (2009b) GIS helps to organize data and understand spatial relationships providing a basis for making more sensitive and intelligent decision making.

Mapping for educational purposes is not a new concept, according to the available evidence, School Mapping (SM) originated in France in 1963 (Caillods et al., 1983; Govinda, 1999; Galabawa, Agu, and Miyazawa, 2002). However, digital school
mapping is a new approach to the micro planning of school locations. This is also used to examine and ensure the efficient and equitable distribution of resources throughout the school system when large scale reform or significant expansion of an educational system take place (Caillods, 1993). However, in the modern world, digital school mapping is widely used due to the development of computer technology, Information Technology (IT) and related software and hardware industry. Other advantages of digital mapping are less storage capacity, easy sharing, easy modification from time to time, and time saving in rapid development and usage.

With the rapid development of digital mapping technology, the application of GIS has become more popular among the policy planners and decision makers, and administrative authorities in the education sector as well as in other sectors which are banking, communication, graphic design etc. GIS is a powerful technology plus computer software capable of advanced geo-spatial analysis. The basic advantage of GIS is the possibility of linking geo-spatial data with their attribute information. The capability of storing maps with object attributes is the most advantageous factor when compared to other databases. Therefore it can create quires using complex criteria like other databases (Ms Access, Oracle) and the result not only contains the numerical information but also the related maps. So GIS based mapping has more advantages than cartographical representation of a particular mapping. As a process that produces specific functional products school mapping is fundamentally an educational micro planning effort focused on increasing school resource efficiency and equity (Caillods et al., 1983; Varghese, 1979).

According to Caillods et al. (1983) and Vargese (1979) GIS based School Mapping (SM) is most often used to facilitate one or more of six listed functions in developing countries.
1) Create the necessary conditions for achieving primary and secondary education.
2) Increase access for females and members of other traditionally under represented socioeconomic groups.
3) Promote the equitable distribution of educational benefits within and between different regions and populations.
4) Improve the quality of educational efforts.
5) Optimize the efficient use of existing capital, human and financial resources.
6) Organize, coordinate and rationalize efforts at technical, vocational and postsecondary level education.

The possibilities of GIS to improve education planning have been identified by Caillods et al. (1983, p.15-18) and Varghese (1997, p.12) as followings.

1) The selection of a unit or unit of analysis for the School mapping exercise
2) A diagnosis of the existing education situation
   a. Existing inequalities in access by impacted area
   b. Efficiency issues such as replication and dropout rate (wastages)
   c. Disparities in elements affecting equality such as facilities, teachers, equipment and supply
3) Detailed projection of enrolment demand potential, including definitions of optimal catchment areas for the school
4) Estimation of numbers and identification of locations for new schools or improvement.
5) Estimation of facilities, resources and supplies to be provided in schools
6) Cost estimation

The above evidence has determined the use of GIS for school site selection which is used in this study.

Another practical example presented how GIS has been used as more than a mapping tool is found in an investigation of the impact of space and place on educational outcomes in Northern England (Fotheringham et al., 2001). They utilized GIS generated maps in this presentation to show the impact of the spatial conditions on the key stage performance of 3687 schools that were the primary focus of the study. They have used
geospatial weighted analysis for this task. As an example they were able to account for the spaces and places that conditions generating socio economic status actually influence education performance rather than analyzing numbers intended as proxies for these conditions.

As stated by Hite (2008) all available school level data can be displayed in instantly available formats. Thus any data associated with a particular school can be accessed directly during the interactive session. The ecological impact of this type of user controlled scenario building and data access and exploration possibilities positively establish the power and utility of GIS in school mapping and Micro planning exercises.

GIS for educational planning and school mapping has been much used in recent years to make better decisions in the education planning sector. GIS base mapping and database provides a wide-ranging framework and association of spatial as well as non spatial data has become an efficient tool to assist planning and decision making. GIS for School Education systems has been used in many instances in developed countries as well as in developing countries.

2.3.1 GIS Applications for School Development

Decisions governing school education planning and development strongly need geographical thinking. Therefore GIS is very effectively used in the education sector today. There are a large number of researches and study articles have been done related to education services, planning, mapping, utilization and accessibility analysis (Ayalasomayajula et al., 2011; ESRI, 2009a; Abdullah, 2008; Al-Hanbali, 2004).

The Geospatial multi criteria decision support model was presented by Liddle (2012) to school site suitability assessment in Durham, North Carolina. He developed this model including a number of related criteria with the possibility of changing their effective values to the model. This is because; the weight given to particular criteria in making the final decision may be changed according to geographical area. The purpose of this Durham model was to increase the capacity of country schools by selecting suitable land for new school site location to provide the schools in a high demand region.
Practical evidence is reported from a South Asian country applying GIS for mapping to overcome the challenges of information management of around half million students and around two thousands schools in Nepal (Banskota, 2009). According to his explanation GIS school mapping is a better way to overcome challenges. The digital mapping of educational institutions along with the Village Development Committee (VDC) boundary, road access, river and major settlements provide the ground reality in terms of spatial and social coverage (Banskota, 2009). The Higher Secondary Education Board (HSEB) in Nepal has been using GIS mapping technology as an Educational Decision Support System (EDSS) by visualizing reality on the ground. HSEB of Nepal used GIS to map the higher secondary schools and assess the accessibility of the feeder schools in the periphery of these higher secondary schools.

This GIS project comprises of the physical location analysis of the higher secondary schools and secondary schools and identification of feeder schools within the margin of higher secondary schools. In order to determine the potential secondary schools (feeder schools) each of the higher secondary school's spatial digital coverage of the road, settlement, river, bridge, population of the particular area are required. Accessibility analysis is done on the basis of the location and attributes of the above-mentioned layers. The Global Positioning System (GPS) as well as analog maps are used to depict the new school as a point layer. Other statistics are managed as attribute data in the attribute tables of the higher secondary schools. According to accessibility and spatial analysis, the necessary decision is made. The GIS mapping project supports HSEB-Nepal for granting affiliation, finding out examination centers and selection of particular schools for particular purposes. Further, this education development project was implemented in Nepal so that they could be helpful in identifying suitable schools to establish secondary education development units at the district level (Banskota, 2009).
Inouye et al. (2008) evaluated factors relating to bike path possibilities around schools for a case study of three middle schools in Washoe County, Nevada using the GIS framework. In addition to the limited length of bikeways, other factors for bicycle use included connections of bikeways to the schools and ratios between road bikeway, and student capacity of the school. The study concluded that the accessibility of a school takes into account all kinds of transportation as well as the population, geography and built environment.

The address information system has always been important for systematically recording school student information and effective routing of school buses (Lilian et al., 2002). Using the GIS technique a student information database combining their living area could be developed. As a result, this system makes it possible to provide student distribution, transport requirements and also future development needs.

2.3.1.1 GIS Integrated School Enrollment Projection

School student enrollment projection is one of the major challenging areas faced by school education planners. Determination of the student intake boundary and student enrollment forecasting has many advantages for future developments. Use of GIS techniques is the most relevant way to overcome this challenge, because GIS has the power to consider the ground situation.

Practical experience is the South California school enrollment projection program that was conducted by the Southern California Association of Governments (SCAG) (Choi and Wang, 2006). School enrollment plays a significant role in estimating school related trips in the transportation modeling process of the SCAG. According to the estimated records, school related trips account for more than 10 percent of the total personal trips that occurred during any single day. Hence, the aim of this entire project is better transportation by successful projection of school enrollment. In this research they have considered neighbor populations of each school and projected the number of new schools and transportation requirements. The result of applied enrollment projection is especially important for better student transportation plans of today and in the future. With this new projection SCAG have considered a wide range of future needs in relation to population growth, accessibility to individual schools, possibility of
expanding existing schools or building new schools, and availability of suitable land for new schools. To obtain this information they followed sequential GIS analysis as follows.

1) “Small area population projection modeling
2) Facility location modeling
3) Land suitability analysis
4) Spatial interaction modeling” (Choi and Wang, 2006, p.3)

Using this analysis they were able to find school enrollment needs and transportation needs for better future planning.

2.3.1.2 GIS for Student Transportation Development

School student transportation using the shortest and safest path is one of the challenging matters in school planning. Minimizing travel time is important for school students to manage their limited time. There are many practical examples and research on solving this travel time problem using GIS analysis. The evidence shows that research to develop a new approach using GIS and modeling to improve the accuracy of small area school enrollment projections, used as input the running regional transportation model for Southern California. Accurate school enrollment projections would help to increase the credibility of the results of the regional transportation model.

The new approach utilizes a facility location model, land suitability analysis, a spatial interaction model to develop location of a new school and related school enrollment. The GIS techniques which include a surface model and a location model are used in the land suitability analysis (Choi and Wang, 2006, p.1). In this context, the evidence reported important GIS analysis for school mapping and decision making. Some of those analyses have already been used in this research. It was found that there are many similarities in both research and analytical research methodology.
The researchers Yildirim and Aydinoglu (2007) presented a GIS based school administration model with solutions for the school catchment area in Turkey for the Commissions of Directorates of National Education. This project included development of a GIS database for the city school district with base maps and related spatial data. They applied network analysis technology in GIS to optimize the routes of school buses to residences of the students.

GIS network analysis widely applies to determine the shortest path or service area of interconnected linear features, road network, rivers, electric lines, pipelines (ESRI, 2009b). Network analysis was applied for reducing school bus routes to minimize student traveling time and cost. In this context there are wide range of researches have been undertaken for school bus route optimization (Derekenaris et al., 2001; Andres, 2004; Handa et al., 2007).

2.3.1.3 School Facility Location Modeling

The facility location model is used to find optimal school location minimizing the total distances between student home (demand point) and potential school (facility). The distance between two objects can be measured by many calculation methods Euclidean distance, Manhattan distance, p root squared distance which is known as physical distance, cost distance or time distance (Yoon and Yoon, 2004). Euclidean distance is the most widely used distance method. It is used in school site selection model by Choi and Wang, (2006) and also in the present research to calculate distance between two schools. According to Ottensmann (2000) Euclidean distance is normally used for simple computational analysis.

2.3.1.4 GIS Network Analysis for Determine the Service Area

A wide range of GIS applications has been developed for linear features that are interconnected. This is called network analysis. Most service routes are inter connected as networks for example highways, railways, roads, utility distribution like electricity, telephone, and water supply. Collectively these networks provide the infrastructure for a modern society. The development, utilization, and management of these infrastructures are very important. GIS network analysis is able to provide advance solutions for
network based spatial analysis similar to routing, travel directions, finding the closest facility, and service or catchment area analysis. This analysis is also used to examine speed limits, height restrictions on vehicles and traffic conditions at different times of the day (Elizabeth, 2005).

GIS Network Analysis can be used to determine;

1) Shortest path
2) Route directions
3) Drive time analysis
4) Point to point routing
5) Service area definition
6) Optimum route
7) Closest facility
8) Origin destination analysis

The definition of school catchment area is one of the major crises in Sri Lanka today. GIS can provide valid solutions to define catchment areas properly. Various analyses and studies can be done with student attendance boundaries such as the number of students within boundaries, calculation of future demand and future changes of the boundaries (Matt, 2005).

GIS analysis has become a commonly used way of defining school catchment area and determining the shortest or safest school bus route. The researcher, Nayati (2008) states that school bus routing and scheduling are among the major problems because school bus transportation needs to be safe, reliable and efficient. According to Nayati (2008), increases in population have resulted in high demand for public transportation in most Indian cities. This situation has created the need for a well organized public transport service. GIS could be very helpful in designing school children’s bus routes and the distribution of other school transportation services. Many schools around the world are using GIS and finding it very easy and helpful to operate. The Indian researcher Nayati has planned a GIS based school transportation management system which helps in bus stop allocation, and designs the fastest and safest bus routes.
Similar research has been done by Yildirim and Aydinoglu (2007) in Turkey to determine school catchment area. They have developed an Automatic Student Registration (ASR) model based on GIS, relational databases and address information. This model allows planners to capture, store, and update analyze, display and permit remote accessing of data. The ASR has been tested with actual data sets of Trabzon city in Turkey.

The main function of the study includes;

1) Building up the digital coverage of the city
2) Forming attributes of the coverage
3) Determination of the school catchment areas based on maximum walking distance and on age distribution of the students by GIS technology.
4) Optimization of the routes of school buses based on residences of the students using network analysis in GIS

Population projection has been used to determine the future demand for existing schools and the construction of new schools by considering the size and age composition of the population in the study area. The small area population projection is designed using many methods. The most popular method is a comparative method based on trends in the small area population and the relationship between large area population and small area population (Davis, 1995). Other small area population projections are based on Micro-geographic land use and activity models.

According to Forster (2000) the greatest use of software packages with an element, or component of GIS technology is at an operational level e.g. routing, scheduling service area analysis, tracing or navigation.
2.4 Multi Criteria Decision Analysis (MCDA)

The use of the Multi Criteria Decision Analysis (MCDA) method is very important since it has a significant effect on the final outcomes. The characteristics and properties of MCDA should be compatible with the specific nature of the decision problems (Vincke, 1995; Laaribi et al., 1996; Salmainen et al., 1998).

The (MCDA) is a formal methodology for using the available technical information and stakeholder values to assist decision making in many fields. According to the available research articles and practical evidence MCDA is widely used in land suitability analysis, environmental impact assessment, and finding optimal site for locating public facilities (Liddle, 2012; Huang et al., 2011; Ahmed and Latif, 2007). It also ensures accuracy in the sense that it has an inbuilt method to check the inconsistency of judgments (Ramanathan, 2001). Several terms have been used to refer to Multi Criteria Decision Analysis (MCDA). Another widely used two of them are Multi Criteria Analysis (MCA), and Multi Criteria Decision Making Analysis (MCDM) (Malczewski, 2006).

The MCDA widely applies for selection of optimum site for public facility to improve the accessibility and to overcome facility disparities. There are many studies that have been done in many countries during the past decades. This technique is based on mathematical theory which is graph-theory. Using this theory some testing methods were developed such as the P-Medium problem, suitability mapping and other techniques by many researchers.

Malczewski (2006) has published an article under the GIS based Multi criteria decision analysis development and he reports the number of refereed articles published in 1990-2004.

There were 10 articles between 1990 and 1995 and this number increased to 40 when year 2000 very rapidly and 319 articles were published in last five years. He presents the growing number of MCDA related researchers with a statistical review and also by a graphical presentation as shown in Figure 2:1. He has collected this information using several web based scientific search engines, electronic libraries, and databases.
The research conducted by Ahmed and Latif (2007) to select optimum sites for public schools followed the Multi Criteria Decision Making (MCDM) approach. Their proposed approach has a two-step analysis to identify the best location for public services. First they used MCM to select suitable sites for the principal schools in an urban area. They then used a location allocation analysis method to identify the optimum site from the sites selected by first step as shown Figure 2.2 this concept was implemented in rural Egypt with funding from UNICEF.
Land suitability using multi criteria analysis uses sources of information related to hydrologic, geologic, and biologic features of a site, accessibility of a site and (for infrastructure and urban land uses), and socioeconomic features (Berke et al., 2005). Land suitability analysis uses overlay maps of various features. They have introduced four analytical methods for suitability analysis.
1) Pass/fail screening (by minimum acceptable rating).
2) Equivalent rating (suitability value for each type of features for a particular land use).
3) Weighted rating (weight to each feature).
4) Direct assignment rating (based on a combined examination of data from all features).

The weighted method is used in this study and it is the wide applications in the GIS suitability analysis (Choi and Wang, 2006; Bukhari, 2010; Zhu et al., 2005). In the weighted method the highest total scores represent the most suitable land use. And the weighted rating is the most widely used method for MCDA applications.

Total Suitability is calculated as in Mendoza (2000); Choi and Wang (2006)

\[ S = \sum_{j=1}^{n} C_j X_j \]

Where S= Suitability measure
\( x_j \) = are the factors affecting suitability
\( C_j \) = parameters associated with each factor

According to Mendoza (2000) GIS is a computer based system with a convenient and powerful platform to perform suitability analysis and allocation. Integration of the multi criteria system of suitability assessment and allocation method into a GIS system offers both spatial capabilities of GIS and the analytical power of multi criteria decision making tools.

A GIS based study done by Raghavendran (2001) used a multi criteria analysis (MCA) approach to display to potential residents the advantages of living in a particular apartment complex for residential apartments in a city of India. He has used ten factors and ranked them on a scale of ten points. He has considered accessibility to city, education facility, railways, bus services, health care services and availability of ground water under the ten factors. As a result this decision support system (DSS) provided rapid and optimum decision in selection of a site for a home for buyers as well as
sellers. The DSS is very important in this task because anybody will buy at least one home in one’s lifetime (Raghavendran, 2001).

Other evidence is about the use of the MCA approach by Zhu et al., (2005) to analyze the accessibility to different factors for a house development project. In this study they interviewed nearly five hundred residents and summarized their responses to calculate the average score of each factor and its rank. This research provided the result by using GIS to determine the overall attractions of an area for housing development from a demand view (Zhu et al., 2005).

Janssen (2001) provides examples of MCDA used in environmental impact assessment in a range of application areas at different spatial scales in the Netherlands, where public participation in environmental decision making is institutionalized. In these applications MCDA is applied to highlight the differences among alternatives and GIS plays an increasing role in environmental impact assessment applications where geo reference data are used as inputs to the MCDA (Higgs, 2005). According to Cloquell-Ballestter (2007) the use of multi criteria analysis to aid decision making should be inherent in studies undertaken within the framework of environmental impact assessment.

A considerable number of GIS integrated studies are available which access the availability of health care services, mapping and modeling of the service accessibility and utilization in many countries. However this literature survey considered only some recent studies which have been based on GIS analyses and modeling.

Evidence shows that GIS based MCDA application solution was applied to classify the major, general and local hospitals in Ireland by the government (Kologirou el al., 2006). They used a weighted MCA approach to measure the possible accessibility based on travel time, hospital size and population. They used this measure to study different scenarios to determine the actual situation.

Another research for health care sector presented by Higgs (2004) that web based GIS system integrating geographic reference data in real time. These web GIS developments have been used in the health sector in Saudi Arabia. An example of the application is
King Abdul Aziz university hospital and King Faisal Specialist hospital which has developed a web GIS based national diabetes registry capable of providing information on the extent and type of diabetes including patients' information and their geographical locations.

Stroke, cancer and myocardial infarction are the three key causes of death in Japan (Ohta et al., 2007). These researchers have applied GIS and MCA by an Analytical Hierarchy Process to increase geographical accessibility to the neurosurgical hospital services for the elders in Japan. They developed different site planes for a new neurosurgical hospital in the city using spatial data about the location of that hospital, population data, roads and numerical data for AHP. According to the reported information a comparison was conducted to find alternatives using the weighted method for four criteria.

- Availability of hospital beds: 0.674
- Maximum road distance of the shortest path: 0.169
- Elder population within 3km radius: 0.101
- Median road distance of the shortest path: 0.056

Researchers Lin et al. (2002) found that overall hospitalization in British Colombia, Canada is negatively correlated to the distance to the hospital. This research was aimed to identify the effect of the travel distance on total and on available hospitalization in three regions in British Columbia and Canada. They have used spatial reference to the hospital locations and patients' homes to determine travel distance to each hospital. They have considered several geographic factors such as steep slope, mountain, road-crossing, and link the patients' homes to the socioeconomic variables. Since this was a success it has been recommended by the Health Department of Canada.

Liddle (2012) has presented a geospatial school site suitability analysis model based on the MCDA approach in Durham, North Carolina which is quite similar to the present study. The purpose of this Durham project was to increase the country school capacity by selecting suitable land for new school location as a solution to large crowds in the existing school system. Liddle conducted his study considering accessibility, safety and environmental issues as the main criteria.
The MCDA approach by Liddle (2012) focuses on overcoming disparities in the high school facilities distribution system in Durham, North Carolina. He has followed a special GIS technique, namely the Model builder analysis method to determine the optimally suitable locations. Further, ArcGIS model builder was used to generate all analyzed maps. ArcGIS model builder is an automated analysis method which integrates all sub analyses together. The Figure 2.3 shows the automated processing operation model for creating multi ring buffers and distance analyses which was used by Liddle.

**Figure 2.3:** ArcGIS Model for Create Multi Ring Buffers

*Source: Liddle, 2012, p. 8*

Another important step in this suitability analysis is the reclassification of each criterion according to its importance in relation to the final suitability marks. Liddle (2012) reclassifies each raster layer using a common measurement scale of 1 to 5. He assigned the highest values to the most suitable scale of sub criteria. Then these reclassified raster layers were applied to generate suitability maps to access the main criteria. Therefore, weighted values were applied to the criteria considering effectiveness to the final suitability results.

The GIS based MCDM suitability assessment creates a more accurate analysis according to Mendoza, (2000) based on experience of application to United States schools. However the GIS based model has never been used in Sri Lanka to select the right school development site. Therefore this research study will be a very important application in school planning and decision functions.
2.5 Experiences of School Site Selection Policies and Criteria

Selecting a new school site is based on the relevant criteria. Current School site selection procedures are different as well as similar in different countries. In this context, most countries have considered primarily four dimensions that are listed below (Liddle, 2012; MESL, 2010).

1) Accessibility  2) Environment  3) Safety  4) Demand

The study by Liddle (2012) was aimed at solving the Durham public school system's struggle to meet the educational needs of the community. He has proposed the need for new public high schools and has considered thirteen related criteria in the final assessment of the new school site selection that are listed in Table 2:3. These criteria have been selected with contributions from many related agencies; policy planning, environmental, and educational. Liddle's criteria list mainly covers accessibility, environment issues, safety, and high demand locations.
### Table 2.3 Main Criteria and Polices for Durham High School Site Selection Project

<table>
<thead>
<tr>
<th>Main Criteria</th>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environment</strong></td>
<td>Slope</td>
<td>Slope in degrees, derived from LiDAR.</td>
</tr>
<tr>
<td></td>
<td>Land cover</td>
<td>All undeveloped areas. Excludes 11 water bodies.</td>
</tr>
<tr>
<td></td>
<td>Managed areas</td>
<td>Includes public and private lands and easements that are of some conservation interest</td>
</tr>
<tr>
<td></td>
<td>Significant Natural Heritage Areas (SNHA)</td>
<td>Areas containing ecologically significant natural communities or rare species.</td>
</tr>
<tr>
<td><strong>Safety</strong></td>
<td>FEMA flood zones</td>
<td>100 and 500-year flood zones.</td>
</tr>
<tr>
<td></td>
<td>Hazardous waste sites</td>
<td>Sites that are regulated by the Resource Conservation and Recovery Act (RCRA)</td>
</tr>
<tr>
<td></td>
<td>Fire stations</td>
<td>Any location where fire fighters are stationed.</td>
</tr>
<tr>
<td></td>
<td>Emergency medical services (EMS)</td>
<td>Any location where EMS personnel are stationed.</td>
</tr>
<tr>
<td></td>
<td>Police stations</td>
<td>Any location where police officers are regularly based or stationed.</td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td>Libraries</td>
<td>Location of libraries.</td>
</tr>
<tr>
<td></td>
<td>Public high schools</td>
<td>Location of public high schools.</td>
</tr>
<tr>
<td></td>
<td>Major roads</td>
<td>Interstates and highways</td>
</tr>
<tr>
<td></td>
<td>People under the age of 15</td>
<td>Number of people under the age of 15 per census tract</td>
</tr>
</tbody>
</table>

**Source:** Liddle (2012, p. 4)

The following list shows the school site selection criteria of the California Department of Education, listed in the order of importance (Department of Education California, 2004).
1) Safety  
2) Location  
3) Environment  
4) Soils  
5) Topography  
6) Size and Shape  
7) Accessibility  
8) Public Services  
9) Utilities  
10) Cost  
11) Availability  
12) Public Acceptance  

Although according to the Ministry of Education Sri Lanka has not clearly pointed out the environmental and safety factors unlike many other countries (MESL, 2010). However, they have mentioned the importance of factors such as geographic conditions, environmental conditions and accessibility. Therefore, the selection criteria are the same as in other countries which we have referenced (Liddle, 2012, Choi and Wang, 2006).

Ahmed and Latif (2007) have conducted research regarding GIS based spatial analysis and optimization techniques to generate optimal facility locations in Egypt. They were proposing a GIS technique to select candidate site and the optimum locations from these sites using GIS multi criteria analysis to identify suitable land parcels which can accommodate schools. These researchers used seven criteria which are listed below.

1) Land use  
2) Building type  
3) Building height  
4) Building condition  
5) Density  
6) Demand points, and Road network
According to the information given above they have considered only three factors – that is accessibility, safety of the building and demand for this suitability analyze. They have not considered environmental factors in this research.

Sri Lanka has most recent practical experience of school site selection using criteria for 1000 secondary school development project in 2010. Therefore, it is useful to study the 1000 school development project.

"Selection procedures should strictly be conducted associating available school data, geographical information system data, student flow analyses and zone and divisional level officials' own professional experience. School mapping techniques should be used to ensure more rationalized distribution of schools with secured access to all children." (MESL, 2010, p. 9)

According to the reports of the MESL (2010), Sri Lanka is considering local and global features as seen in the following list of criteria:

1) Geographical location and road access
2) Number of students in the primary and secondary schools
3) Patterns of student flow to the selected school and surrounding schools
4) Distance to the secondary school from the primary feeder schools
5) Available and required spaces in the school
6) Access to public facilities and government administrative offices
7) Pattern of demographic changes and population growth in the area
8) Availability/ if not available, whether access can be established for electricity, communication
9) Cultural and environmental factors and any special circumstances
10) Feasibility for rational deployment of subject specific teachers in the school
11) Selection of a good principal
12) Leadership capacity of the principal
School site selection is affected by many factors, including health and safety, location, and size. But the site selection team often is unable to locate a site that meets all the criteria agreed on. Therefore it should set priorities and be prepared to make certain compromises. In addition, the team must weigh those site characteristics that may adversely affect the choice. Careful assessment takes time, but the importance of each decision justifies the attention.

Multi criteria analysis could be particularly useful in situations where there are a large number of alternative sites for development, and a large number of potential criteria to be taken into consideration or where subjective judgments by different stakeholders on the different alternatives are a factor. It is necessary to try to reach an objective consensus in the final decision making process to make these processes more open and accountable (Higgs, 2006).

According to the Karjalainen et al. (2013) value focused MCDA can support the identification and valuation of ecosystem services in the Environmental Impact Assessment process. Lahdelma et al. (2000) state that a discrete multiple criteria decision problem consists of a limited set of alternatives that are evaluated in terms of multiple criteria. The criteria provide numerical measures for all relevant impacts of different alternatives.
CHAPTER 3

MATERIALS AND METHODS

3.1. Introduction

This chapter introduces the design of the study in details, it includes study area, conceptual frame work, identification of criteria, data collection methods and database, further the theoretical framework, empirical strategy and the analytical methods has been used in this study in order to achieve the research objectives. And also the hardware software and tools which were used to the data analysis in the study were presented.

3.2. Study Area

3.2.1 Geographical Location

This study is focused on the Homagama Divisional Secretariat Division (DSD) in Colombo district, located in Western Province of Sri Lanka. The geographical background of the study area is presented in Figure 3.1. The problem is very common to the whole country but it is essential to select a suitable area for the necessary data collection due to limited time for the study.

The Homagama DSD is situated in the western province in Sri Lanka and city area is 21 km away from the city of Colombo. This area located geographically between (6.5631N, 80.03446E), (6.47213N, 79.55382E), (6.50290N, 80.05049E) and (6.45002N, 79.57464E). The land extent of this area is about 133 sq.km including 81 Grama Niladari Divisions (GND). The estimated population of the study area is 236,201 according to the census of year 2012.
Figure 3.1: Geographical Location of the Study Area
3.2.2 Existing School System of the Study Area

There are 38 government schools in the study area and, 31 of them are primary schools and the rests are secondary schools. Table 3.1 shows the existing school system and Table 3.2 shows the demand and pressure for the popular schools in the study area.

**Table 3.1: Number of Schools by Type in the Study Area**

<table>
<thead>
<tr>
<th>No.</th>
<th>School Code</th>
<th>Description</th>
<th>Number of schools</th>
<th>Administration by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Type 1AB</td>
<td>All A/L subject streams with science subjects</td>
<td>01</td>
<td>Provincial</td>
</tr>
<tr>
<td>2.</td>
<td>Type 1C</td>
<td>A/L subjects without science</td>
<td>06</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Type 2</td>
<td>Year 1 to 11</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Type 3</td>
<td>Year 1 to 8 or 1 to 5</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>38</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Ministry of Education Sri Lanka, 2012: (School Census Data)

**Table 3.2: Grade 1 Application for the Popular City Schools in the Study Area**

<table>
<thead>
<tr>
<th>School</th>
<th>Type</th>
<th>Num. of grade 1 applications</th>
<th>Number of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homagama M.V</td>
<td>Type 2</td>
<td>993</td>
<td>2,506</td>
</tr>
<tr>
<td>Homagama M.M.V</td>
<td>Type 1AB</td>
<td>No Data</td>
<td>2,375</td>
</tr>
<tr>
<td>President college</td>
<td>Type 1C</td>
<td>920</td>
<td>2,782</td>
</tr>
<tr>
<td><strong>Subharathi M.V</strong></td>
<td>Type 2</td>
<td>679</td>
<td>1,593</td>
</tr>
<tr>
<td><strong>Yuda Hamuda V.</strong></td>
<td>Type 3</td>
<td>659</td>
<td>1,085</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>3251</strong></td>
<td><strong>10341</strong></td>
</tr>
</tbody>
</table>

Source: Provincial and Zonal Educational Offices and Field Survey

According to the school distribution pattern, most of the principal schools are clustered to the main urban area. Many of the primary or secondary schools are limited to remote areas with minimum educational facility. In examining the official statistics of the
Ministry of Education it is evident that there is no national level school in the Homagama Divisional Secretariat Division. The only one Type 1AB provincial School which conducts all AL subject steams also situated in the Homagama town area and another two popular type 1C schools are located in the same area. This situation has created many education disparities and socio economic crises in the society as listed below.

- High demand for the few urban schools and which have insufficient facilities.
- Student’s travel distance to the school and time have been increased
- Large number of students are attend to outside schools from living area
- Parents have to spend more money for the student transport from their monthly income
- Students spend highest amount of time in risky areas like accident, air pollution and health hazards.
- Leads to a decline in the learning capability of the students badly

3.3. Methodology

The potential school site selection for further development as the principal school is not a simple or single task. Because the selection of a suitable school site is depends on geo spatial factors. Therefore in order to achieve the main objective which is to identify a potential school sites for sustainable development, the GIS integrated Multi Criteria Decision Making (MCDM) analytical approach was selected.

The selection an area could be used to identify suitable school land to a new principal school for the study area. The GIS is the most widely and reliably used decision making tool for the spatial related matters in the modern world today. The following Figure 3.2 is presented illustrate the methodology for the study.
Identification of the Problem

Identification of Study Area

Literature Survey

Data Collection

Field/Primary Data

Informal Interviews

Spatial Data

GPS Locations

Field Verification

Secondary Data

Attribute Data

Spatial Data

Toposheets

Google earth

Data Preparation and Storing

GIS Based Data Analysis

Suitability School Map

Figure 3.2: Research Methodology
3.3.1 GIS and MCDA

The Geographic Information System (GIS) is a special computerized Data Base Management System (DBMS) used to capture, store, manage, retrieve, analyze, and display spatial data. GIS is a special and different from other database systems and graphic systems in many ways. The data used in the GIS system are geo reference to the coordinates on particular standard projection systems. With this combination of coordinate system and data the precise location on the earth’s surface could be created. This is allows the creation of spatial relationships between data and objects/map features.

![Figure 3.3 Capability of GIS, Overlay Digital Map Layers](image)

Common reference system data could be overlaid to determine the relationships between data layers. For example land use data from a particular area in different years can be overlaid to identify the nature of changes within the time period. The Figure 3.3 demonstrates use of overlay different map layers to identify ground spatial problems or incidents such as patterns, hotspot, and resinous for decision making. These constitute the base of a GIS system and also the power behind many simple and complex analyses.
The next main advantage of the GIS is capability of link spatial data with attribute data. Hence, it can be display information/attributes of any map objects in the same location on the map as demonstrate by Figure 3.4. This feature is special for the GIS when comparing other information systems.

Many scientists have defined the accomplishment of the GIS as;

GIS is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from real world (Burrough, 1986, p. 6).

According to the definition of Clarke (1986),

GIS is computer-assisted Systems for the capture, storage, retrieval, analysis, and display of spatial data (Clarke, 1986, p.175).

GIS is a combination of computer hardware and software that are used to capture, store, reference, manipulate, analyze, manage, and present all types of geographical data. One of the main advantages of GIS system over other database systems is the ability to retrieve attributes data plus related maps using the above criteria. According to Cropper (2003) the power of the GIS has been referred to as smart mapping because the user can help to identify feature attributes on a map just by clicking a mouse.

![Figure 3.4: Capability of GIS, Link Attribute Data with Spatial Data](image-url)
The Environmental Systems Research Institute (ESRI) defines and explains GIS as:

“A geographic information system (GIS) integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information.

GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts.

A GIS helps you to answer questions and solve problems by looking at your data in a way that is quickly understood and easily shared. GIS technology can be integrated into any enterprise information system framework” (ESRI, 2014, p.1).

The GIS integrated Multi Criteria Decision Analysis (MCDM) approach was applied for the school site suitability assessment in this study. This GIS integrated MCDM method is based on the Analytic Hierarchy Process (AHP) which was developed by Saaty (1980). The basic of the AHP is a complex problem separated into multi level hierarchical structure to determine the relative significance of each criterion. This method could be used to handle both qualitative and quantitative data. The AHP and its significance in suitability analysis have been well presented by many researchers (Bayliss et al., 2003; Carver, 1991). The AHP helps to decision makers to analyze the complex problems by making the problem easier to be understood.
3.3.2 Conceptual Framework of the Study

The set of conceptual steps could be used to assist develop a model as a reality to achieve the objectives. The Figure 3.5 is presenting the conceptual model in the study.

![Conceptual Model of the Study](image)

**Figure 3.5**: Conceptual Model of the Study

3.4 Data Collection and Preparation

3.4.1 Identification of Criteria and Defining Policies

The research is an attempt to select the optimal school site to improve as Principal/facility school using MCDA approach. Therefore, clearly identification of the appropriate criteria for the analytical model is needed before the data collection is started. The data collection was based on definition of the criteria for the suitability analysis. Primarily the criteria identification was based on guidelines of the conceptual paper of the Ministry of Education published for the providing equitable access for the educational national program (MESL, 2010). The Ministry of Education had not even attempted to determine individual criteria of school site selection. Also they have not strongly considered safety and environmental criteria. In this context, item vise
individual criteria were selected under the three main criteria as presented in Table 3.3. However, this research carefully considered guidelines used by other leading countries by reviewing, investigating and comparing their reports and studies. This is assist to determine fulfill and qualitative list of criteria for school site selection study considering accessibility, safety and environmentally effects.

**Table 3.3:** The List of Considered Criteria and Policy Description.

<table>
<thead>
<tr>
<th>Main Criteria</th>
<th>Criteria</th>
<th>Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>Distance from principal schools</td>
<td>Schools should not be within 1 km of other principal schools</td>
</tr>
<tr>
<td></td>
<td>Population density</td>
<td>Schools should be demand locations</td>
</tr>
<tr>
<td></td>
<td>Distance from main roads</td>
<td>Schools should be located near to good road network but should be not very near main roads</td>
</tr>
<tr>
<td>Safety</td>
<td>Distance from commercial area</td>
<td>Schools should not be very near to major towns and it should be away 500 m from commercial areas</td>
</tr>
<tr>
<td></td>
<td>Distance from industrial zones, other risky areas</td>
<td>Schools should not be near to industrial zones, flood area, deep water bodies, etc</td>
</tr>
<tr>
<td>Environment</td>
<td>Land Cover</td>
<td>School land must be large enough to provide accommodation a high school</td>
</tr>
<tr>
<td></td>
<td>Land Slope</td>
<td>Schools should not be built on land with steep slop</td>
</tr>
</tbody>
</table>

### 3.4.1.1 Distance from Principal Schools

New principal school site should be away from the existing developed schools to avoid encroaching on their catchment areas to provide wider service to the community. In order meet equity and quality a resource sharing system, it is highly acceptable maintain sufficient distance in between principal schools. Therefore 1km was selected for appropriate school distance for the study. Three schools were identified as existing high demandable schools of the study area based on more than 2000 students and highest number of new admissions as shown in Table 3.2. Input dataset for the analysis was popular school points under this criterion.
3.4.1.2 Population Density

Schools must be established in demand locations because student’s travel time, road traffic, parent’s income, county fuel wastage and many socio economic factors depend on it. If people have quality education facility in their living area it is very impotent to reduce student travel time. At present in this situation it is highly acceptable that in Sri Lanka a large number of schools are away from student living area. Also this case is highly related with determination of proper school catchment area. Catchment area of the schools or boundary is not clearly defined at the percent in Sri Lanka. Therefore, in this study, high population density areas were selected as criteria to locate the new principal school. Input dataset for the analysis was GND vise population under this criterion.

3.4.1.3 Distance from Main Roads

Schools should have good accessible road facility but it should not locate very near to the main roads because of noise, air pollution and many other reasons (Amram et al., 2011; Joshua et al., 2012). On the other hand, heavy traffic of the school time period is one of the main problem in Sri Lanka today. In this case, students are faced with difficulties to travel on time to schools and their homes. Also vehicle transportation generates polluted substances which have bad effects to the human health. Several research reports have been published regarding student’s health risk due to schools near major road network and have a high risk of heart and lung problems (Salvesen, 2008; Green et al., 2004). Considering these experiences road distance limitation is determined and 500 m distance was selected as appropriate main road distance for the study. Input dataset for the analysis was main road network map under this criterion.

3.4.1.4 Distance from Industrial Zones

Schools must be located away from hazard zones which are flood affected area, deep water bodies, fuel stations and also industrial zones. In this study it has been considered industrial area such as industrial area reserved by government and stone quarries based on UDA prepared land use map for the Homagama DSD. The particular study area has one major industrial area and a number of stone quarries and other industries. Other
hazard locations were not considered due to very low risk according to the geographical background of the study area.

School must be located away from industrial areas because of the safety risk caused by the air pollution and high noise. On the other hand, there is a possibility to occur explosion depending on the nature of the industry. Many education departments of well planned countries already have been concerned and had included this factor in their school site selection guidelines (Department of Education in California, 2004; Department of Education in Georgia, 2003). In this study, the distance from industrial areas to schools were recommended at least 500 m based on the previous studies and experience (Abdullah, 2008). Under this criterion, input dataset for the analysis was Industrial zones layer.

3.4.1.5 Distance from Commercial Area

Commercial area is not suitable for school sites due to heavy traffic, noise and air pollution. Therefore schools should not be located in the commercial area or very near. In this study distance from schools to commercial areas suggested as 500 meters considering size and nature of the productions to minimizing the risk. But most acceptable distance is at least 1km between commercial area and schools (Bukhari et al., 2010). Input dataset for the analysis was commercial area layer under this criterion.

3.4.1.6 Slope of the Land

When a school is located in a deep slope location it creates many problems. The Ministry of Education has considered the slope factor as a site selection criterion under the geographical location (MESL, 2010). Several studies have proposed and recommended 10° or less than for social facility development sites (Bukhari et al., 2010). Therefore 10° or less than slope value was assigned as most suitable to the study data layer, obtained from the Department of Survey. To find areas of relatively, it needs to create a map displaying the slope of the land. Hence, the process model here involves calculating the slope of the land. Input dataset for the analysis was the elevation map under this criterion.
3.4.1.7 Lands Availability for Development

Selected schools should have sufficient land for development needs in the future as a capable major school that will provide improved service to a wider community. On the other hand insufficient land availability is affected to sport development and also to the health environment of the students. Therefore input dataset was size of the school land under this criterion.

3.4.2 Data Collection Method, Data and Data Sources

In this research both spatial data and non spatial attribute data were used to perform multi criteria analysis. Two main types of data capture are;

- Primary data sources which are collected in digital format specially for using GIS projects.
- Secondary sources which are digital and analog datasets that were originally captured for another purpose and need to be converted into a suitable digital format for using GIS projects.

Basically the most of the secondary data were obtained from various related institutes in Sri Lanka as presented in Table 3.4.
### Table 3.4: Details of the Collected Data

<table>
<thead>
<tr>
<th>No.</th>
<th>Layer / attributes</th>
<th>Formats</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>School locations</td>
<td>Ms Excel</td>
<td>By self survey</td>
</tr>
<tr>
<td>2.</td>
<td>Population</td>
<td>Ms Excel</td>
<td>Department of Census &amp; Statistics</td>
</tr>
<tr>
<td>3.</td>
<td>School attributes</td>
<td>Ms Excel</td>
<td>Department of Education, Western Province</td>
</tr>
<tr>
<td>4.</td>
<td>DSD boundary</td>
<td>Shape file</td>
<td>Department of Survey</td>
</tr>
<tr>
<td>5.</td>
<td>Land use</td>
<td>Shape file</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Contours</td>
<td>Shape file</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Roads network</td>
<td>Shape file</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Principal schools</td>
<td>Shape file</td>
<td>Field survey and Google map</td>
</tr>
<tr>
<td>9.</td>
<td>Commercial area</td>
<td>Shape file</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Hazard zones</td>
<td>Shape file</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>DSD Land use</td>
<td>Pdf file</td>
<td>Urban Development Authority (UDA)</td>
</tr>
</tbody>
</table>

School Data: Geospatial coordinates of the schools for the Homagama Educational Zone could not be obtained due to unavailability of early studies or geospatial survey in this field direct to the area. Therefore school point layer was developed under two methods that geographical coordinates were captured using Google imagery base self developed web page and also via field survey using hand held GPS device to collect unavailable school points on Google map. The method of capturing coordinates values from Google imagery is shown in Figure 3.6 below.
Other required spatial and attribute data are collected from primary or secondary sources such as Department of Survey and Department of Education. In addition, interviews were held with some related educational authorities to have a better background knowledge. Among those institutes, the Ministry of Education, Education Ministry of Western Province and zonal education office of the Homagama provided the major contribution for background information and also to share related ideas on this study.

All geospatial school locations were combined with the school attributes data such as school type, number of students, teachers, and land size etc. Then it can be used to create queries based on various criteria to understand the resource allocation. The Digital maps include graphical data as school locations, road network, contours, and land use and population density. The Table 3.5 displays the data layers and their attributes.
Table 3.5: Data Layers and Their Attributes

<table>
<thead>
<tr>
<th>No.</th>
<th>Layer Name</th>
<th>Attribute Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>schools</td>
<td>Name, Zone, Division, Address, GND_C, Type, Students, Teachers, Sci_Room, Home_Slab, Computers, G1_Apply, Class_Rooms, …</td>
</tr>
<tr>
<td>2.</td>
<td>population</td>
<td>GND_N, GND_C, GNArea_Ha, Total_Pop, Male, Female, Age_0_15, Age_15_59, Grater_60</td>
</tr>
<tr>
<td>3.</td>
<td>land</td>
<td>School_Name, Type, Address, L_Acres, L_Rood, L_Perches, Mud_Acres, Mud_Rood, Mud_Perches, PGround</td>
</tr>
<tr>
<td>4.</td>
<td>contour</td>
<td>Length, Elevation, Terrain, Feet, Shape</td>
</tr>
<tr>
<td>5.</td>
<td>mainroads</td>
<td>Shape, Name, Length, GFCode</td>
</tr>
<tr>
<td>6.</td>
<td>commercial</td>
<td>ObjectId, Name, Area, Perimeter, Location</td>
</tr>
<tr>
<td>7.</td>
<td>industrial</td>
<td>ObjectId, Name, Area, Perimeter,</td>
</tr>
</tbody>
</table>

3.4.3 Data Storage Method of Study

Database planning is the one of the most significant activity in a GIS based project. The database used in GIS known as geo database because of the possibility of geographical reference of the objects. Therefore this is the most important fundamental step of the process in the analysis (Chawala and Shekhar, 2003).

The Geo database is used to store all collected data layers and attributes with a common environment in GIS software. The collected data from various sources were in different formats and different coordinate systems. Therefore it was needed to convert all these data in to common database environments. Then, geodatabase technique was chosen to store the data due to many advantages to the model.
There are three types of geodatabase in GIS;

- Personal geodatabase
- File geodatabase
- ArcSDE Geodatabase

In this study personal geodatabase was used to store all the data, taking into account data type, number of the data layers and access limitation to the database.

The special advantage of using personal geodatabase in this type of study is the possibility to convert different layer coordinate system and different spatial reference system into one coordinate and reference system which is set in the geodatabase. Another importance of geodatabase is the possibility to manage data set as folder vise based on the category under the facility of feature class and dataset. The format of the personal geo-database in ArcGIS is same as MS Access or MS Squeal. Therefore it is easy to develop, manage and create data queries.

**Properties of the Spatial Dataset;**

Coordinate system of the School point, commercial area and industrial zone layers which are extracted from Google map transformed from WGS84 to survey department parameters of Sri Lanka.

Parameters of the spatial referencing system used in the ArcGIS model are shown in bellow.

Projected Coordinate System: Kandawala_Sri_Lanka_Grid

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projection</td>
<td>Transverse Mercator</td>
</tr>
<tr>
<td>False Easting</td>
<td>200000.0</td>
</tr>
<tr>
<td>False Northing</td>
<td>200000.0</td>
</tr>
<tr>
<td>Central Meridian</td>
<td>80.771711</td>
</tr>
<tr>
<td>Scale Factor</td>
<td>0.9999238418</td>
</tr>
<tr>
<td>Latitude of Origin</td>
<td>7.0004802777</td>
</tr>
<tr>
<td>Liner Unit</td>
<td>Meter</td>
</tr>
</tbody>
</table>
3.5 Data Analytical Procedure

Data analysis was conducted primarily on GIS Multi Criteria Decision Making (MCDM) analysis approach as introduced in the methodology section. The collected data in the personal geodatabase was analyzed using the model builder technique in ArcGIS spatial analyst tool and analysis was conducted on main three steps.

1. Create the Geo-Spatial database.

2. Develop the model using Multi Criteria Analysis approach to identify potential schools for principal schools.

3. Identify the suitable existing school site for principal schools under the selected criteria.

3.5.1 Evaluation Selected Criteria with MCDA Approach

The selected seven criteria were arranged according to Analytical Hierarchy Process (AHP). Then all the criteria were divided into sub groups based on the MCDA approach. The Figure 3.7 displays hierarchical structure of the school suitability analysis process.
The all seven criteria were applied for decision making process by assigning numerical rank for the all selected criteria considering advantages to the model.

3.5.2 Identification of Potential School Locations

To develop suitability map, it should be combined with all selected map layers together to have a single ranked map of potential school land for the development. Therefore all input vector layers want to convert into raster layers for calculate the observation figures of each input layers which are distance to main road, popular schools, main commercial areas, and hazard zones and also the amount of slope, population and size of land. The result of the creating a suitability map is that it enables to obtain a suitability value for every location on the map. Then it should be weighted all these layers considering the percentage value of advantage to the model to select the most appropriate schools for establishing principal safety schools.
3. 5.2.1 Reclassify All Input Layers

It is important to identify the scale of suitability of the each school location regarding each and every data layer. Therefore all derive input raster layers were regrouped/reclassified on a desired common scale considering the site selection criteria and regulations. This ranking is done by assigning a value to each class in each layer on scale of 1 to 5, where 5 for the most suitability and 1 represent the least as follows.

Range of Suitability Values on Utility Scale:

- Utility scale values normalize all input raster datasets.
- The cells of each input raster in the analysis are assigned suitability values from the utility scale.

3.5.2.2 Weighting and Combining the Suitability Maps

The last step of the suitability model development is to combine all the reclassified output suitability maps to produce the final map. The main considerable point of this step is impotency ratio of the objectives to the model. The well known fact is it is not equally important that all inputs to the model. In this case, some objectives have more importance in the suitability model, therefore it should weight the dataset considering the rate of importance it should have more importance in the model a higher percentage influence/weight than the others.

The Figure 3.8 and related information below explains the method of the raster weighting in the ArcGIS analysis.
Method of assign weights values to inputs

- Each input is weighted, or assigned a percentage influence, based on its importance.
- The total influence for all inputs must be equal to 100 percent.
- Total Suitability = (criteria₁ * weight₁) + (criteria₂ * weight₂) + ... + (criteriaₙ * weightₙ)

Figure 3.8: Example of Combination, Weighted Two Raster

This process was conducted based on the weighted liner combination method of the MCDA (ESRI, 2009; Mendoza, 2000; Liddle, 2012) as present in following mathematical formula. All criterion score Xᵢⱼ for n factors should be added and multiplied with the relative important weight value Wᵢₙ which are obtained from the export score value in selecting the suitable school for the new principal school, Sᵢⱼ as following mathematical formula;
\[ S_{ij} = \sum_{m=1}^{M} x_{ij} W_m \]

Where

- \( S_{ij} \) = Suitability score of \( ij \) location
- \( x_{ij} \) = Criterion score for \( m \) factor of \( ij \) location
- \( W_m \) = Weight age of relative importance for \( m \) factor
- \( m \) = Consideration criterion or factors

The final suitability map was created by combining all weighted layers using ArcGIS weighted overlay tool. Assigning weighted values was done by giving the weighted values to all the input by percentage of influence of each input layer. The highest percentage value for the most influence input and lowest for the least influence input was assigned.

In this study, the most preferable to satisfy is to locate the school at a more distance to existing popular schools in the area and next are population, main roads, industrial zones, commercial area, size of the land, and land slope in order. Used weighted values for each raster are presenting in the chapter 5 under the analysis section.
CHAPTER 4

ANALYSIS, RESULTS AND DISCUSSION

4.1 Introduction

The first section of this chapter discusses the way in which the data has been analyzed for the study in order to achieve the objectives presented in chapter 1. The next section presents the final outcome of the research analysis and discussion. In this context, the created spatial school data layer, the developed model, the final suitability map and existing projects, evaluation map are visually presented.

4.2 Analysis

The analysis is comprised of the following sections.

- Creating a geospatial database to store data and develop the school data layer
- Developing a model, based on multi-criteria analysis to identify the existing schools for develop as principal schools and produce the suitability map
- Developing an overlay analysis to evaluate the final map with the existing project locations

☐ Creating the Geo-database for the Analysis

The ArcGIS personal geo-database was created to store data of the analysis. The personal geo-database that can store, query, and manage both spatial and non-spatial data in a common coordinate system and common environment. Therefore, all input data layers were inserted to the personal geo-database. As a result manly coordinate system of the all data layers transform to Kandawala and to the working area defined as Homagama DSD.
4.2.1 Geospatial Data Layer for Schools

The next step was to develop a geospatial school data layer for the study area. Collection of school information was conducted as two separate activities at different time periods. In this context, under the first section geographical coordinates of the school locations were collected with the school name, address, Grama Niladari Division (GND) and GND Code on a Microsoft Excel sheet. Next, these points were uploaded to the Google Earth to check the ground reality and make the correction before insert to the personal geo-database as X, Y dataset. Secondly the collected school attributes were added to the School data layer using ArcGIS attribute merge tool based on GND Code as foreign key field. The Result of the developed school spatial data layer was presented in the result section in the chapter 4.

4.2.2 Model for Identification of Potential School Locations

The main analysis part of this study is GIS integrated multi criteria analysis based model for determining the optimal school sites to upgrade as principal schools. The model was developed using the ArcGIS Model Builder facility and weighted overlay tool. The ArcGIS model builder provides a better control environment for the input factors and it has the capability to change the result of the model by changing its parameter values. Therefore this model could be practiced for any other different educational divisions without changing all. The developed ArcGIS model is presented under the result section of this chapter.

In this study, mainly all analyses conducted as raster analysis, therefore, it should be convert all input data layers to raters. In this case, The ArcGIS Euclidean Distance Tool was used to calculate distances to existing principal schools, distance to main roads, distance to commercial areas, and distance to industrial zones to calculate and convert to raster layers. The population density and land availability were calculated by ArcGIS Kernel Density Tool and slope of the land calculate by creating a raster Digital Elevation Model (DEM). The results of these three calculations are deriving raster layers for individual factors.

Next, it is important to analyze and study scale of suitability of each factor by evaluating against their comparative advantages and disadvantages. In this context, the
multi criteria approach provide the possibility to reclassify individual factors into several classes. Then, this ranking was conducted using the ArcGIS Reclassify Tool according to the decided conditions which was discussed in the methodology chapter. In this way, suitability values were assigned on suitability scale 1 to 5 with 5 for the highest distance which is the highest preference to locate a principal school. Finally the composite suitability map was developed by applying ArcGIS weighted Overlay Tool, to all suitability maps with developed school data layer. The used methodology for the MCA is presented in Figure 4.1.
Figure 4.1: Followed Methodologies for MCA
4.2.2.1 Distance from Popular Schools to Potential Sites

To avoid the catchment areas of other principal schools it is important to know the distance to them. Hence, the Euclidean distance tool was used to create the distance raster map. As a result, it has produced a raster dataset in which every cell represents the distance to the nearest popular school (Figure 4.2). Then this raster was used to rank the distance values by re-class spatial analysis tool according to the criteria presented in Table 4.1.

**Table 4.1: Accessibility Criteria for Distance to Popular Schools**

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Class</th>
<th>Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1000</td>
<td>1</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>1000-3000</td>
<td>2</td>
<td>2</td>
<td>Less suitable</td>
</tr>
<tr>
<td>3000-4000</td>
<td>3</td>
<td>3</td>
<td>Moderate suitable</td>
</tr>
<tr>
<td>4000-5000</td>
<td>4</td>
<td>4</td>
<td>Suitable</td>
</tr>
<tr>
<td>&gt;5000</td>
<td>5</td>
<td>5</td>
<td>Most suitable</td>
</tr>
</tbody>
</table>
Figure 4.2: Distances from Popular Schools to the Vicinity of the Study
4.2.2.2 Calculating Population Density and Grouping

The population is representing the demand for the new development. Therefore population is a main factor in this study to reach the goal which is providing the facility to access the education for all. Therefore population density was calculated using Kernel density tool for each GND and creates a population density layer to possibility to perform GIS raster analysis. Demand locations can be determined by the population density therefore, highest score 5 is assigned to the highest density locations as shown on Table 4.2. The Figure 4.3 displays the classified population density raster layer map.

Table 4.2: Accessibility Criteria for Population

<table>
<thead>
<tr>
<th>Population density</th>
<th>Class</th>
<th>Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1033</td>
<td>1</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>1033-1627</td>
<td>2</td>
<td>2</td>
<td>Less Suitable</td>
</tr>
<tr>
<td>1627-2207</td>
<td>3</td>
<td>3</td>
<td>Moderate suitable</td>
</tr>
<tr>
<td>2207-2942</td>
<td>4</td>
<td>4</td>
<td>Suitable</td>
</tr>
<tr>
<td>&gt;2942</td>
<td>5</td>
<td>5</td>
<td>Most suitable</td>
</tr>
</tbody>
</table>
Figure 4.3: Population Density of the Study Area
4.2.2.3 Analyzing Distance from Main Roads to Potential Sites

To avoid the unnecessary difficulties and health effects as discussed above it is required to decide the distance between school and main roads. On other hand the school should not be located in a very far away location from road network. Then it is sensory to maintain the proper distance between main road and schools. Hence schools which are very near to the main roads were decided not suitable if distance between 500 m to 1000m had been considered to most suitable (Table 4.3). In order to calculate the proximity to man roads ArcGIS Euclidean distance tool was used. The result is a raster dataset which every cell represents the distance to the main roads (Figure 4.4). Then this raster layer was used for reclassification.

Table 4.3: Accessibility Criteria for Distance to Main Roads

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Class</th>
<th>Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;500</td>
<td>1</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>500-1000</td>
<td>2</td>
<td>5</td>
<td>Most suitable</td>
</tr>
<tr>
<td>1000-2000</td>
<td>3</td>
<td>4</td>
<td>Suitable</td>
</tr>
<tr>
<td>2000-3000</td>
<td>4</td>
<td>3</td>
<td>Moderate suitable</td>
</tr>
<tr>
<td>&gt;3000</td>
<td>5</td>
<td>2</td>
<td>Less suitable</td>
</tr>
</tbody>
</table>
Figure 4.4: Suitability of the Study Area Based on Distance from Main Roads
4.2.2.4 Distance Between Commercial Areas and Potential Sites

As same as the main road, to avoid effectiveness from commercial areas to the school is highly applicable as discussed earlier. The Spatial Analyst straight line distance calculation was used to identify 500 meter unsuitable area around the commercial areas. Then the created raster dataset was classified according to the distance and apply score values like less than 500m is not suitable. The scores of distance and the output raster layer are displayed in Table 4.4 and Figure 4.5 sequentially.

Table 4.4: Accessibility Criteria for Distance to Commercial Area

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Class</th>
<th>Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;250</td>
<td>1</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>250-500</td>
<td>2</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>500-750</td>
<td>3</td>
<td>4</td>
<td>Moderate suitable</td>
</tr>
<tr>
<td>750-1000</td>
<td>4</td>
<td>5</td>
<td>Suitable</td>
</tr>
<tr>
<td>&gt;1000</td>
<td>5</td>
<td>3</td>
<td>Most suitable</td>
</tr>
</tbody>
</table>
Figure 4.5: Distances from Commercial Area to Vicinity of the Study Area
4.2.2.5 Distance from Industrial Zones to Potential Sites

There is a possibility to develop risky environment by the neighborhood hazard zone of a school. Accordingly, safety is one of the most important factors when locating a school. To determine the distance to hazard zone, the spatial analyst straight line distance function was used in this study and produced raster map (Figure 4.6) was used to reclassify as following Table 4.5.

Table 4.5: Accessibility Criteria for Analyze Distance to Industrial Zones

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Class</th>
<th>Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;250</td>
<td>1</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>250-500</td>
<td>2</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>500-750</td>
<td>3</td>
<td>4</td>
<td>Moderate suitable</td>
</tr>
<tr>
<td>750-1000</td>
<td>4</td>
<td>5</td>
<td>Suitable</td>
</tr>
<tr>
<td>&gt;1000</td>
<td>5</td>
<td>5</td>
<td>Most suitable</td>
</tr>
</tbody>
</table>
Figure 4.6: Distance from Industrial Zones to Throughout the Study Area
4.2.2.6 Analyzing and Ranking Land Availability

Size of the land cover is another important factor in any kind of site selection project other than this. Because the project should have sufficient land to successes in the target development and also future development needs. Collected school point layer has included the land size of the schools in acres. Then these values were used to create the raster layer and regroup according to decided land sizes. The details of the re-classing and the put raster map are displayed in Table 4.6 and Figure 4.7. However, sometimes land size could be increased by new attachments.

**Table 4.6: Accessibility Criteria to Analyze Land Availability**

<table>
<thead>
<tr>
<th>Land (Acres)</th>
<th>Class</th>
<th>Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.5</td>
<td>1</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>0.5-1.0</td>
<td>2</td>
<td>2</td>
<td>Less suitable</td>
</tr>
<tr>
<td>1.0-1.5</td>
<td>3</td>
<td>3</td>
<td>Moderate suitable</td>
</tr>
<tr>
<td>1.5-2.0</td>
<td>4</td>
<td>4</td>
<td>Suitable</td>
</tr>
<tr>
<td>&gt;2</td>
<td>5</td>
<td>5</td>
<td>Most suitable</td>
</tr>
</tbody>
</table>
Figure 4.7: Land Availability for New Development in the Study Area
4.2.2.7 Deriving Slope from Elevation Data and Ranking

Many countries have shown advantages of flat land for school sites as discussed in chapter 3. So considering this experiences slope of the land had been considered for the study. Ten degrees have been recommended for the proposed developments school site in order to obtain the better environment facilities and the areas of relatively flat land are favorable to build schools.

ArcGIS slope analysis tool was applied to calculate the slope and as the result it creates continues raster layer. Next the raster layer was reclassified according to the slope level and the scale factor. The assign scale factors and classified map are presented in Table 4.7 and Figure 4.8. Since, the study area is not a mountainous or high land when comparing other area of the country, therefore, low influence (5%) is accepted for the slope factor.

Table 4.7: Accessibility Criteria for Analyze Slope

<table>
<thead>
<tr>
<th>Slope (0°)</th>
<th>Class</th>
<th>Score</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>1</td>
<td>5</td>
<td>Most suitable</td>
</tr>
<tr>
<td>5-10</td>
<td>2</td>
<td>4</td>
<td>Suitable</td>
</tr>
<tr>
<td>10-15</td>
<td>3</td>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>15-25</td>
<td>4</td>
<td>1</td>
<td>Not suitable</td>
</tr>
<tr>
<td>&gt;25</td>
<td>5</td>
<td>1</td>
<td>Not suitable</td>
</tr>
</tbody>
</table>
Figure 4.8: Slope of the Study Area
4.2.2.8. Weighting and Combining the Suitability Maps

This was done by giving the weigh values to all the input by percentage of influence of each input layer. The highest percentage value for the most influence input and lowest for the least influence input was assigned.

Used weighted values for each raster are displaying in the following list. The total influence for all inputs is 100 therefore influence values are presented as percentages; these percentages are divided by 100 to normalize the values and assign to each suitability map. Assigning weight values for suitability maps is a subjective process, depending on what are the objectives that most important to determine the best school sites are as follows.

1. Distance to existing popular schools : 30% (0.3)
2. Main road distance : 20% (0.2)
3. Population : 20% (0.2)
4. Distance to commercial area : 10% (0.1)
5. Distance to Industrial area : 10% (0.1)
6. Slope of the land : 5% (0.05)
7. Land Availability : 5% (0.05)

The final composite suitability map was created by combining all the weighted suitability maps together. The weighted values are assigned using ArcGIS weighted Overlay Tool at the same time inside the model. Then it could be assigned adjusted parameter values to do the experimental study for different result.
4.3 Result and Discussion

4.3.1 Developed Geospatial School Data Layer

As the first step of the study was focused to develop a geo spatial school data layer of the study area is presented to meet the stated the research objectives. The school point layer was developed using the collected geospatial school locations. Attribute table of school point layer was edited by ArcGIS edit tool and insert collected school attribute for each school point. Hence, these school attributes can be access on school digital map with geospatial coordinates as shown in Figure 4.9. Ground verification was conducted to determine the errors and such errors successfully removed. For this reason, planners can observe the ground reality with spatial attribute data by creating queries in many dimension bases on their criteria, and then they can make better sustainable decision.

For an example, suppose the divisional education office wanted to know how the distribution of play ground facility in the area with 400 meters track, then they can produce a digital map using this developed data layer to display the playground with 400 m track. The attribute queries could be developed using Structure Query Language (SQL) on select by ArcGIS attributes tool to accomplish this type of task.
Figure 4.9: Retrieving School Attributes

The school data layer has included information under 46 fields related to all schools of the Homagama educational division. The available attributes of the school layer have been listed in the Table 4.8. The school layer mainly includes School type, Medium, Grades, Number of students and Teachers, Land availability, Lab facility, and sanitary facility. Therefore, this digital data will be more useful decision making regarding schools system of the area.
Table: 4.8: List of Attributes of the Developed School Data Layer

<table>
<thead>
<tr>
<th>No.</th>
<th>Column heading</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ZONE_</td>
<td>Education Zone</td>
</tr>
<tr>
<td>2</td>
<td>DIVISION</td>
<td>Education Division</td>
</tr>
<tr>
<td>3</td>
<td>NAME</td>
<td>School Name</td>
</tr>
<tr>
<td>4</td>
<td>ADDRESS</td>
<td>Address of the School</td>
</tr>
<tr>
<td>5</td>
<td>X</td>
<td>Longitude</td>
</tr>
<tr>
<td>6</td>
<td>Y</td>
<td>Latitude</td>
</tr>
<tr>
<td>7</td>
<td>TELEPHONE</td>
<td>Telephone Availability</td>
</tr>
<tr>
<td>8</td>
<td>NS_PS</td>
<td>National or Provincial</td>
</tr>
<tr>
<td>9</td>
<td>TYPE</td>
<td>Type of the School</td>
</tr>
<tr>
<td>10</td>
<td>MEDIUM</td>
<td>Teaching Mediums</td>
</tr>
<tr>
<td>11</td>
<td>GRADES</td>
<td>Number of Grades</td>
</tr>
<tr>
<td>12</td>
<td>STUDENTS</td>
<td>Number of Students</td>
</tr>
<tr>
<td>13</td>
<td>TEACHERS</td>
<td>Number of Teachers</td>
</tr>
<tr>
<td>14</td>
<td>G1_APPLY</td>
<td>Grade 1 Application</td>
</tr>
<tr>
<td>15</td>
<td>CL_ROOMS</td>
<td>Number of Class Rooms</td>
</tr>
<tr>
<td>16</td>
<td>L_Acres</td>
<td>Land Acres</td>
</tr>
<tr>
<td>17</td>
<td>L_Roods</td>
<td>Land Roods</td>
</tr>
<tr>
<td>18</td>
<td>L_Perches</td>
<td>Land Perches</td>
</tr>
<tr>
<td>19</td>
<td>MUD_Acres</td>
<td>Mud Land Acres</td>
</tr>
<tr>
<td>20</td>
<td>MUD_Roods</td>
<td>Mud Land Roods</td>
</tr>
<tr>
<td>21</td>
<td>MUD_Perche</td>
<td>Mud Land Perches</td>
</tr>
<tr>
<td>22</td>
<td>LFNC_A</td>
<td>Land for New Construction Acres</td>
</tr>
<tr>
<td>23</td>
<td>LFNC_R</td>
<td>Land for New Construction Roods</td>
</tr>
<tr>
<td>24</td>
<td>LFNC_P</td>
<td>Land for New Construction Perches</td>
</tr>
<tr>
<td>25</td>
<td>PGROUND_A</td>
<td>Play Ground Acres</td>
</tr>
<tr>
<td>26</td>
<td>PGROUND_R</td>
<td>Play Ground Roods</td>
</tr>
<tr>
<td></td>
<td>Codes</td>
<td>Description</td>
</tr>
<tr>
<td>---</td>
<td>-----------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>27</td>
<td>PGROUND_P</td>
<td>Play Ground Perches</td>
</tr>
<tr>
<td>28</td>
<td>TRACK_M</td>
<td>Maximum Length of the Running Track</td>
</tr>
<tr>
<td>29</td>
<td>COMPUTERS</td>
<td>Computers</td>
</tr>
<tr>
<td>30</td>
<td>OIL_LAB</td>
<td>O/L Lab</td>
</tr>
<tr>
<td>31</td>
<td>SCI_ROOMS</td>
<td>Science Room</td>
</tr>
<tr>
<td>32</td>
<td>MINI_LABS</td>
<td>Mini Lab</td>
</tr>
<tr>
<td>33</td>
<td>MATHS_LAB</td>
<td>Mathematics Lab</td>
</tr>
<tr>
<td>34</td>
<td>D_UNITLAB</td>
<td>Dental Unit</td>
</tr>
<tr>
<td>35</td>
<td>CHEM_LAB</td>
<td>Chemistry Lab</td>
</tr>
<tr>
<td>36</td>
<td>PHY_LAB</td>
<td>Physics Lab</td>
</tr>
<tr>
<td>37</td>
<td>AGRI_LAB</td>
<td>Agriculture Lab</td>
</tr>
<tr>
<td>38</td>
<td>BZ_BOTLAB</td>
<td>Botany Lab</td>
</tr>
<tr>
<td>39</td>
<td>LIBRARY</td>
<td>Library</td>
</tr>
<tr>
<td>40</td>
<td>ELECTRICIT</td>
<td>Electricity Availability</td>
</tr>
<tr>
<td>41</td>
<td>WATER</td>
<td>Water Supply</td>
</tr>
<tr>
<td>42</td>
<td>STAFROOM</td>
<td>Staff Room Availability</td>
</tr>
<tr>
<td>43</td>
<td>S_HOSTAL</td>
<td>Hostel Availability</td>
</tr>
<tr>
<td>44</td>
<td>COUNSELLIN</td>
<td>Counseling</td>
</tr>
<tr>
<td>45</td>
<td>ACTI_ROOM</td>
<td>Activity Room</td>
</tr>
<tr>
<td>46</td>
<td>HOME_SLAB</td>
<td>Home Science Lab</td>
</tr>
</tbody>
</table>

**Source:** Field Survey and Western Provincial Education Department
4.3.2 Developed Model for School Site Selection

Figure 4.10 shows the weighted overlay model created using ArcGIS model builder facility to select the most suitable school sites for develop the principal schools. The weighted raster overlay analysis is one of the most useful methods in GIS integrated MCDA approach to solve spatial related problems. The model could insert any other criteria and also model parameter can be changed as planner’s decisions such as classification intervals and weighted influence of the criteria.

4.3.3 Selection of Suitability Schools for Development

The study is focused on suitable school selection to upgrade as principal school in order to meet sustainable development. Therefore, the potential school should have completed all the criteria which are discussed in the chapter 3 under the three main criteria accessibility, safety and environment. The seven parameters have contributed to find the suitable existing schools. In this study, two schools were identified as score 5 which is most suitable and these are located away from Homagama central commercial area and they have fulfilled other selection criteria. The details of the selected schools are indicated in the Table 4.9.
Table 4.9: Results: Selected Suitable Schools for Development

<table>
<thead>
<tr>
<th>School Name</th>
<th>Address</th>
<th>Present Type</th>
<th>Longitude and Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Most suitable Schools (Score 5)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jalthara Maha Vidyalaya</td>
<td>Jalthara, Hanwella</td>
<td>Type 2</td>
<td>80.04652, 6.89969</td>
</tr>
<tr>
<td>Siyabalagoda Dharmapala K.V</td>
<td>Polgasovita</td>
<td>Type 2</td>
<td>79.96657, 6.79588</td>
</tr>
<tr>
<td><strong>Suitable Schools (Score 4)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depangoda Sri Medananda M.V</td>
<td>Brahmanagama, Pannipitiya</td>
<td>Type 1C</td>
<td>79.98123, 6.81659</td>
</tr>
<tr>
<td>Palagama Sri Parakum v.</td>
<td>Palagama, Polgasowita</td>
<td>Type 2</td>
<td>80.02533, 6.86229</td>
</tr>
<tr>
<td>Meegoda Maha Vidyalaya</td>
<td>Meegoda</td>
<td>Type 1C</td>
<td>80.04673, 6.85259</td>
</tr>
<tr>
<td>Magammana M.V</td>
<td>Homagama</td>
<td>Type 2</td>
<td>79.99729, 6.82087</td>
</tr>
<tr>
<td>Kiriwattuduwa Jayathilaka V.</td>
<td>Kiriwattuduwa</td>
<td>Type 2</td>
<td>80.02600, 6.80005</td>
</tr>
<tr>
<td>Artigala K.V</td>
<td>Hanwella</td>
<td>Type 2</td>
<td>80.05839, 6.89219</td>
</tr>
<tr>
<td>Meegoda Dharmaraja vidyalaya</td>
<td>Meegoda</td>
<td>Type 2</td>
<td>80.04375, 6.84390</td>
</tr>
</tbody>
</table>

Acceding result of the MCDA approach, there are seven schools selected under the second suitability category. In this case development authority could be selected alternative schools from the list if they wanted. The produced final suitability map with school locations are presented by Figure 4.11.
Suitability of the Existing Schools for Locating Principal Schools

Figure 4.11: Model Output: Suitable Schools for Development
According to the suitability map the selected most suitable two schools which are:

1. Jalthara Maha Vidyalaya – Jalthara Hanwella and

These two schools are located in East and Northwest part of the study area, these locations are displayed within the green color background on the suitability map which is represent the high suitability area as shown Figure 4.11. According to the geographical locations of these two schools, it has accepted fittingness of the model and the result to overcome inequality resource sharing within the area.

Some schools have been identified as less suitable locations for development as principal schools and these most locations are currently urban schools.

4.3.4 Comparing Result With the Existing System

The Homagama M.M.C is the only on 1AB school of the study area which was recently identified to develop as principal school under the Mahindodaya 1000 school project by the Ministry of Education. But according to the result of the study, this school also situated in less suitable area for the sustainable development. The Education Ministry has started another new school site in Pitipana Mahena state though this school also is not included to the most suitable or suitable area. The Figure 4.12 displays the suitability level of these ongoing development project sites.
Suitability of the Existing Schools for Locating Principal Schools

Figure 4.12: Suitability Map Intersects with the Ongoing Schools Development Projects
• For that reason, it is very clear almost all the current school development sites are located on unsuitable or less suitable areas. This situation is explains the following weaknesses of this development plan.

• Education planners have not considered accessibility, safety and environment factors of the new schools.

Therefore these project plans have not identified;

- High demand areas
- Schools in safety locations
- Schools with better environment for development

Hence, the existing development project will not properly address the current education problems of the study area.
CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The GIS is a significant tool for Analysis, Mapping, and Visualization of spatial related data. GIS based multi criteria analysis special analytical method has been used to develop the school site selection model that is presented in this research.

The study and its result illustrate the successful implementation and advantages of applying the GIS technology for education planning and decision making process. The use of GIS technology based modeling for decision support system has created new capabilities and advance assistance to the planning process. GIS is not only an analytical tool, but also a tool to assist planners and administrators to make decisions and also it is realizing the ground reality visually. Therefore GIS based analytical technology has strong possibilities to provide the sustainable solution for spatial related problems. Hence the research is capable to increased the opportunity of access and the quality of education facility of the society.

The most of the parents are attempt to obtain better and quality education for their children from very limited opportunities presently in Sri Lanka. Therefore, there is great need for better strategic planning for education planning and principal school locating and developing. On other hand, school site locating is a special task when considering other facility locating activities. Because a school is must be located at demand location with better environment and safety.

This research shows the evidence of importance of integrating GIS technology to determine the best school site for sustainable development. The presentation is very successful in presenting the way to determine the suitable schools to establish principle schools considering accessibility, environment, and safety. In this context, the GIS technology is a more powerful tool to assist the educational authorities to develop sensory maps in solving complex problems. Therefore this scientific powerful analytical
approach will be more applied to reach the successive education sustainable development in Sri Lanka.

The developed GIS compatible school data layer and suitability map exactly indicate the geographical coordinates of any school location in the study area with its attribute data. Hence, these layers could be used in any GIS analysis regarding schools in this area or research purposes. The education planners can use these digital data to determine resource distribution weaknesses within the area. They can find out subject vice teachers distribution or other infrastructure distribution inequity with higher accuracy. It has more advantages consider the ground truth than use simple data tables to make assessment for this type of spatial related problems.

According to the produced suitability map following two existing schools have been selected to locate new principal schools in the most suitable locations.

1. Jalthara Maha Vidyalaya, Jalthara Hanwella
2. Siyabalagoda Darmapala, K.V, Polgasovita

This result was evaluated by conducting ground observation for verification. Then it has clearly proved the suitability of these schools for further development needs. There are seven schools selected under the second suitable category and all these schools have fulfilled the considered criteria of this study.

The suitability map which was created could be compared with the existing development project location. It has clearly determined the ongoing school development project sites out of the most suitable area. Therefore these projects will not be able to overcome the inequity education facility within the area and address to the quality education demand of the Homagama DSD.

The GIS model developed in this research is economical, less time consuming and more productive than the traditional approaches to potential site selection for locating principal schools. In this case planners can reduce field visits and surveys. The other significant feature of this research is capability to identify all the possibilities at the same time. Therefore this research will be more important to increase the quality and
equity educational facilities for the community of Sri Lanka. Also the research findings provide very valuable information for the education planners and both educational authorities of provincial and national level in the same way to change and enhance their traditional approaches.

On other hand the developed model is a digital tool and this model can be used anywhere in the world with the necessary computer system. Also the model developed in this research is easy to change and it has the facility to build and expand further with inserting more information layers pertaining to all aspects of planning and development needs of school site selection in Sri Lanka.

5.2 Recommendations

The analytical method of this research is more flexible and is a complete approach to school site suitability assessment. As a result the developed model has the possibility to change the existing criteria and their respective weighted values. The considering criteria for the model must be different according to the geographical background of the study area. In this case, some new criteria should be affected to the model such as flooding, deep water bodies, environmental pollution and other new conditions which have not been considered in this study. Therefore, this possibility of changing parameters has many advantages for the future improvements of the model.

The present model was developed as a desktop application hence, it cannot be access from remote location to use or update timely chargers. Therefore, it will be very important to improve as a server based application to possibility update the database by regional office of schools.

The result shows the weakness of the existing site selection system for the principal schools therefore in Homagama DSD. Hence, provide a sustainable solution to overcome the main problem in school education sector which is high demand for few major schools is still challenging. Therefore, it should be applied GIS integrated well planning technologies for decision making process in site selection for principal schools and also equitable facility sharing among the schools.
Selecting a most suitable location is highly needed for sharing facilities or services among the society. GIS is capable of providing better geospatial solutions to overcome facility sharing problems in the school education system. Therefore, GIS application in the education sector is more applicable and should be trained for education planners in Sri Lanka to turn to sustainable development.
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APPENDICES

(a.)
List of Closed Schools in Homagama Educational Zone
From Year 1995 to 2001.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of School</th>
<th>Date of Closed/Year</th>
<th>Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ho/Gurulgomi Vidyalaya</td>
<td>1995.03.15</td>
<td>Homagama</td>
</tr>
<tr>
<td>2.</td>
<td>Ho/Kirigam Pamunuwa Primary School</td>
<td>2000.08.01</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Ho/Nawalamulla Primary School</td>
<td>1995.06.28</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Ho/Veniwalcola Primary School</td>
<td>1998</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Ho/Uggalla Sirisumana Vidyalaya</td>
<td>1999.05.01</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Ho/Hewagam Estate Tamil Primary School</td>
<td>2001.06.01</td>
<td>Padukka</td>
</tr>
<tr>
<td>7.</td>
<td>Ho/Horagala Primary School</td>
<td>1995.02.26</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Ho/Thummodara Primary School</td>
<td>2001.03.01</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Ho/Kahawala Primary School</td>
<td>2001.06.01</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Ho/Udugam Kanda Primary School</td>
<td>2001.06.01</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Ho/Mawalgama Primary School</td>
<td>N.D</td>
<td>Seethawaka</td>
</tr>
<tr>
<td>12.</td>
<td>Ho/Kahatapitiya Primary School</td>
<td>1997.09.10</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Ho/Pahala Hanwella Ro, Primary School</td>
<td>2000.08.01</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Ho/Kosgama Balika Vidyalaya</td>
<td>1997.01.01</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Ho/Elamalawala Primary School</td>
<td>2000.06.28</td>
<td></td>
</tr>
</tbody>
</table>

Source: Zonal Educational office Homagama, 2014
13th January 2014

Zonal Education Office
Court Road,
Homagama.

Dear Sir / Madam,

Re: Requesting data available for the research purpose

Mr. K.D. Nethsiri Jayaweera follows the M.Sc. Degree programme in GIS and Remote Sensing at Faculty of Graduate Studies, University of Sri Jayewardenepura. As a component of this degree program, he has to conduct a research project which includes spatial analysis of secondary data and submit a dissertation. Accordingly Mr. K.D. Nethsiri Jayaweera is keen on conducting a research under the topic of "Integrating Geo Special technologies for development of schools; with special reference to Homagama Educational zone" This analysis would help in developing local government operation system of your Department as well. Therefore please be kind enough to grant Mr. K.D. Nethsiri Jayaweera access to the data available with your Department.

Your kind assistance in this regard is much appreciated.

Thanking you.

Head/Department of Geography
Western Province Department of Education
Greenpath,
Colombo 07.

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[Signature]
13th January 2014

Ministry of Education
Isurupaya,
Battaramulla.

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