Analysis of Locational Suitability for Residential Development in Colombo Sub Urban Area: Application of Analytic Hierarchy Process

E W M L R K Ekanayaka
KGPK Weerakoon[1]

Abstract

Urbanization is a continuous process and it results in attracting people to urban areas for better living. As a result demand for residential land is prominent in the surroundings of cities and urban sprawl is a common phenomenon that exists in most developed and developing countries. Therefore cities face with the most challengeable task of providing land with better infrastructure to fulfill this demand. In this case situation of developing countries is more aggravated due to the lack of proper planning regulations and economic inefficiency. This is a common phenomenon in the city of Colombo which is the commercial capital of Sri Lanka. It is still developing and gradually residential demand pressure is being exerted on surrounding urban areas. Planning regulations are not strong enough to avoid negative consequences of urban sprawl. Therefore most of the residential areas are unable to meet better living conditions. Therefore identification of suitable land for residential development is the most important task in planning and it is observed that present zoning regulations cannot fulfill this requirement. Selection of suitable land for residential purposes is a complex process in multifunctional pattern of urban areas and a scientific approach has been used for that.

Geographic Information System (GIS) is a powerful tool that can be used to analyze spatial data and its sophisticated analysis functionalities with multi criteria evaluation provide a better approach for suitability analysis. This paper aims to do a suitability analysis to identify possible locations for residential development in the Colombo Urban Area. GIS with Multi-criteria Evaluation (MCE) is used to analyze data. The process of land suitability analysis involved evaluation and grouping of specific areas of land in terms of their suitability for a defined use. Integrated GIS and MCE process add some valuable insight to a strong analysis platform for finding suitable residential locations. This research aims to demarcate suitable areas for residential development using the above techniques. The scientific classification used is in line with the zoning plan of the study area and it can be used as a guide map to the zoning plan of the study area

Keywords - Geographic Information System, Residential Suitability, Suitability Analysis, Multi-criteria Evaluation, Analytic Hierarchy Process, Pair wise comparison

[1] Department of Estate Management and Valuation
University of Sri Jayewardenepura
Email: kgpk@sjp.ac.lk

Introduction

Presently, more than half of the world population lives in urban areas and considerably half of the population in developing countries also live in urban areas. The urban population in developing countries was increasing at an alarming rate during the last 50 years as a result of push and pull factors influenced from third world urbanization. The significant feature of the third world urbanization is the concentration of urban population in and around metropolitan areas and mega cities. Due to high demand for residential use, population is unevenly scattered in the urban edge of the metropolitan areas. This problem is more aggravated in the developing countries and mushroomed slums and squatter settlements is the result. These overcrowded residential areas have no access to affordable facilities for a better living. Therefore residential land development plays a major role in the urban development. Due to the scarcity of land, real estate developers are concern on vertical development rather than horizontal development. Most real estate developers try to maximize their profit margin and pay less attention for selecting best locations.

The residential developments required to focus on the affordability of the residents to live and work with accessibility, infrastructural facilities, environmental quality, financial ability etc. But most of the real estate developers mostly concern on financial affordability of the buyer and not the social and environmental factors. Then in the long term residents face many difficulties in day to day living in those perticular locations. Therefore evaluation of locational suitability of the residential development is most important to a country to provide a better living for people. In the long term a country with a good living environment can earn good benefits from the society, and it maximizes the highest and best use of the land. Geographical Information Systems (GIS) and Multi Criteria Evaluation (MCE) can be used as a tool to analyze locational suitability of residential development. Choosing an appropriate location for residential use is obviously related to decision support and MCE. The problem can be generalized as a question of what must be done and where it should be realized.

Sri Lanka has achieved a substantial economic growth since 1977 after the introduction of the liberalized economic policies, which has resulted a sharp increase in economic activities. As a result the land market within the Colombo Metropolitan Region is being rapidly growing up. This factor is directly related to the cost of development. According to the high growth rate of population due to internal migration and natural growth, demand for housing increases continuously. As a result, the stakeholders in the property market sector had launched residential development either horizontally or vertically, based on the factors such as location, demand, user requirements, availability of land, development regulations etc., in order to satisfy housing requirements of the urban areas. But the most challenging problem is meeting the demand for urban infrastructure facilities and lack of access to good quality, affordable and reliable services. The current demand for infrastructure and services far outstrips supply in most areas. Governments generally invest little in infrastructure and this undermines the economic growth, private sector development and the achievement of social and poverty reduction goals.

With these underlying situations property developers in the country are engaged in real estate investments during the past decades. They mainly aimed to fulfill only their economic gain and profit margin and not the concept of better living. Therefore policy makers need to prepare proper guidelines for suitable areas for residential development. Present zoning regulation provides only a set of basic guidelines and no guidance on proper locations for future residential development. Identification of the land scientifically based on Physical, Socio-economic factors are essential for residential development. Hence this study attempts to identify and evaluate the locational suitability of planning and implementation residential development using a scientific methodology.

Objectives of the Study

General objective of this study is to evaluate the locational suitability of the residential development in Colombo sub urban area using GIS integrated Multi Criteria Evaluation (MCE). To achieve this general objective, following specific objectives were developed.

i. To identify the criteria for locational suitability for residential development in Colombo sub urban area.
ii. To develop a GIS-MCE integrated framework for identified residential development.
iii. To identify suitable developable lands for residential purpose in the study area using GIS.

Relevant Literature

Affected Factors for Location of Residential Use

Better residential development is based on several factors. Belching (2000) investigated the factors which determine the acceptable residential location. He mentioned different factors which are highly significant in locational suitability for residential development such as accessibility, neighborhood quality, environmental Quality, negative environmental influences (pollution, traffic etc), environmental factors (wetland, wildlife, senic rivers etc), desired infrastructure, reasonable size and design, surrounding uses, excessive traffic congestion and additional factors (historical development, topographical features and size, dynamic changes and, government Policy). Those factors highly affect the residential uses and these factors should be considered when selecting a suitable location. This process cannot be carried out manually because all factors cannot be given the same weight. Therefore comparison of the factors is essential for this process and a scientific process is needed accordingly.

Land Suitability Assessment

Sherry (2000) highlights the land suitability analysis is "the process of determining the fitness of a given tract of land for a defined use". In other words, it is the process to determine whether the land resource is suitable for some specific uses and to determine the suitability level. The different types of land-use suitability studies can be attributed to the different ways the term land use is defined by various applications and the context of its use. For example, it is expected that the urban planners and the agricultural experts concern different perception of the term. However land suitability assessment provides better insights to future demarcations of land allocations.

Historical Perspective

With the increasing demand for land, land use planning and land evaluation have become more important as people strive to make better use of the limited land resources. Land evaluation is the process of assessing land performance for specified purposes (Rossiter, 1996). As well as land suitability assessment, a typical analysis approach for land evaluation is the process of determining the fitness of a given tract of land for a defined use (Steiner, 1991). It is an indispensable part of land evaluation in the process of land use decision-making. Accordingly, it can argued that land use planning is a technical process which deals with physical, economical, environmental as well as social factors of users of that area.

Since 1950s, land suitability assessment has been used in land evaluation processes in many western countries (Wu, 2000). In the beginning, there was no conformity in the standards and methods used in land suitability assessment. Since land evaluation approaches differed from country to country, information exchange was rather difficult. It was not until 1976 that the fundamental document for land evaluation, proposed by the Food and Agriculture Organization of the United Nations (FAO), "A Framework for Land Evaluation", was published. The framework described the procedures of land evaluation and the classification of land suitability. A universally accepted and a systematic standard for land suitability assessment was the most important contribution of this framework. After "the Framework for Land Evaluation" was published, the FAO developed specific land evaluation frameworks for irrigation, grazing and rained agriculture. Since the 1990s, land evaluation has become a synthesis of the land capability and land suitability assessment in many countries (Wu, 2000). This kind of development in land suitability assessment generally helps to have highest and best use in any area and gradually it moves from agriculture to other areas such as residential, industrial as well as office locations.

Land suitability assessment was introduced to China in the end of 1970s. In the past decades, land suitability assessment has been adopted as an important part of land use planning in rural areas, urban areas and the fringe of urban and rural areas of China. In China, land suitability evaluation for a given crop is the most widely used aspect of land suitability assessment (Fang and Liu, 2004). Since China is one of the best agricultural countries in this part of the world, they used this technique to utilize their land usage in to the highest percentage.

In comparison, land suitability assessment has played a very limited role in the process of urban development. Urban sprawl, urban edge development and unplanned development are some of the serious land use problems which should be given more attention in most of the countries in Asia as well as in Europe. Land suitability assessment can help planners to select appropriate areas for government activities, residential land use, and industrial land use and so on. By taking the results of land suitability assessment into development consideration, the planners and decision makers can plan the future land use planning properly and maximize benefits from the use of land resources.

Along with the development of computer technologies, Geographic Information System (GIS) has been developed rapidly in the past twenty years. Since 1990s, GIS have been applied to land suitability assessment for managing spatial data and presenting visual results.

Land Suitability Analysis

Land suitability analysis is one of the most useful applications of GIS for planning and management (McHarg, 1969; Hopkins, 1977; Collins *et al.*, 2001). Land-use suitability analysis aims to identify the most appropriate spatial pattern for future land uses according to specified requirements, preferences or predictors of some activity (Hopkins, 1977; Collins *et al.*, 2001). In order to determine the most desirable direction for future development, the suitability for various land uses should be carefully studied with the aim of directing growth to the most appropriate sites.

Shalabi (2006) stated that, establishing appropriate suitability factors is the base for construction of suitability analysis. Initially, suitability analysis was developed as a method for planners to connect spatially independent factors within the environment and consequently to provide a more unitary view of their interactions. Further, Shalabi (2006) stated that, Suitability analysis techniques integrate three factors,

a. An area- location
b. Development activities
c. Environmental processes.

These techniques can make planners, landscape architects and local decision-makers to analyze factors interacting in various ways. Moreover, such suitability analysis enables elected officials and land managers to make decisions and establish policies in terms of the specific land uses. The GIS-based land-use suitability analysis has been applied in many different studies during the last two decades, some are; geological assessment (Bonham-Carter, 1994), agricultural suitability (Cambell *et al*., 1992; Kalogirou, 2002), landscape planning (Miller *et al*., 1998), selecting the best site for the public and private sector facilities (Eastman *et al*., 1993; Church, 2002), and regional planning (Janssen and Rietveld, 1990). Also, "the diversity of the types of land-use suitability studies can be attributed to the different ways the term land use is defined by various applications and the context of its use" (Malczewski, 2004).

The aim of suitability analysis is to identify the best areas for some activity given the set of potential (feasible) areas. In this type of analysis all the characteristics (such as location, size, relevant attributes, etc.) of suitability should be concerned and have to be given a rank compared with all criterions. Based on criterion analysis the alternative areas can be identified. This multi-criteria analysis is somewhat a difficult task but in the last decade scientists were unable to overcome this challenge and they introduced different methods for multi criteria evaluation.

GIS based MCE integration tools developed a desired platform for Suitability analysis. In this case GIS techniques and procedures play an important role in analyzing decision problems and MCE provides a rich collection of techniques and procedures for structuring decision problems and designing, evaluating and prioritizing alternative decisions. Therefore GIS-MCE can be thought of as a process that transforms and combines geographical data and value judgments to obtain information for decision making.

Multi-Criteria Evaluation (MCE)

Multi-criteria Evaluation is primarily concerned with how to combine the information from several criteria to form a single index of evaluation. MCE techniques are numerical algorithms that define the suitability of a particular solution on the basis of the input criteria and a weight together with some mathematical or logical means of determining trade- offs when conflicts arise (Heywood *et al*., 2002). A spatial multi-criteria decision problem involves a set of geographically defined alternatives from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria (Carver, 1991, Heywood *et.al*., 1995). The data are processed using GIS and MCE techniques to obtain information for making the decision. The process of spatial multi-criteria evaluation combines and transformed geographical data (input) into a result decision (output). The MCE procedures define a relationship between the input maps and output maps which involves evaluation of geographical events based on the criterion values and the decision maker's preferences with respect to a set of evaluation criterion. "The procedures involve the utilization of geographic data, decision maker's preferences and manipulation of the data and preferences according to spatial decision rules and they aggregate multi-dimensional geographical data and information into undimentional values of alternative decisions" Malczewski (1999). The common procedure of GIS-based MCE is to determine decision alternatives and decision criteria, establish the performance of alternatives in those criteria and aggregate the performance values to a single evaluation score for each alternative in order to create a preference ranking. There are different stages of the spatial multi-criteria analysis involved and in both stages GIS and MCE methodologies are used. In the earlier stages GIS techniques played the major role, while in the later stages, MCE techniques are of major importance. Hence with this combination GIS provide the capabilities until analysis of the data to obtain information for making decisions (GIS has limited capability to analyze the value structure). The MCE techniques provide the tools for aggregating the geographical data and the decision maker's preferences into undimentional value or utility of alternative decisions. Within this process determination of criterion weights are important and Analytic Hierarchy Process (AHP) is one of the best methodologies to be applied.

The Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision making process which helps people to set priorities and make the best decision when both qualitative and quantitative aspects of decisions need to be considered. AHP was developed in 1970's by Thomas Saaty, as a decision-making theory. Tighes (2005) stated that the AHP is a decision making tool that incorporates both qualitative and quantitative factors. By reducing complex decisions to a series of one-on-one comparisons, then synthesizing the results, AHP not only helps decision makers to arrive at the best decision, but also provides a clear rationale that it is the best. The main framework of AHP is a hierarchical model. It comprises goal, criteria, perhaps sub-criteria and alternatives to each problem or decision. Pair wise comparison matrix is most important procedure of AHP. The criterion pairwise comparison matrix takes the pair wise comparisons as an input and produces the relative weights as output and the AHP provides a mathematical method of translating this matrix into a vector of relative weights for the criteria (Malczewski, 1996; Eastman *et al.*, 1995). A decision rule is a method of weighting or scoring criteria to assess their importance (Heywood *et al*., 1993). It is the procedure by which criteria are combined to arrive at a particular evaluation and by which evaluations are compared and acted upon (Eastman *et al.*, 1995). In the pairwise comparison matrix, two elements are compared at a time using a scale that ranges from "extreme important" to "equally important", and their inverses (down to 1:9). Based on the criterion weights derived from the pair-wise comparison matrix, scores for group attributes in the hierarchy are calculated as a weighted average of elements in the group. Following table 1 indicates AHP scales for pair-wise comparisons.

In recent years many researchers used multi-criteria evaluation in various disciplines. For example in Sharifi. M. A., *et, al.*, (2003) (demarcation boundary in the city and National Park), Merwe *et, al.*, (2001) (public decision making for buffer zone demarcation), Kralidis, (1999) (find best location for housing), Kangas, *et, al.,*(2002) (Multi-functional forestry), Zui, (1994); Weerakoon (2002) (Urban land evaluation), Sadek. S., (1999) (root alignments developments), Bannai, (1995) (flood vulnerable analysis).

Table 1: The AHP Scales for Paired Comparisons

Intensity of Importance	Definition
1	Equal importance
2	Equal to Moderate importance
3	Moderate importance
4	Moderate to strong importance.
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to Extremely strong importance
9	Extreme importance

Source: Saaty (1987)

Methodology

Two types of data are used for this research; map data and other data. 1:2000 maps (land use map, road map) prepared by the Survey Department, Sri Lanka was used to make different criterion maps. Other primary data were based on questionnaire survey and unstructured interviews and those were used to demarcate weights for criterion maps. Methodology was developed as a step by step process and it is explained below:

Step 1 - Identification of prioritize criteria: Two types of data were collected for prioritizing criteria, such as questionnaire survey conducted with the residents of newly developed housing schemes and unstructured interviews conducted with experts in related institutions.

Step 2 - Developed criterion maps*:* Based on the given priority preferences 6 criterion were identified and six criterion maps were developed.

Step 3 - Given weights for criterion maps: Calculation of weights for criterion maps was based on the multi criteria evaluation. Saaty's Analytic Hierarchy Process was applied for that. Based on that pair-wise comparison matrix was prepared according to AHP scales. AHP based Expert Choice Computer Programme was used to perform that.

Step 4 - Calculate composite weights and develop final suitability map: Calculate composite weights, based on main criterion weights and each sub criterion weights. Following formula was used.

Composite Weight = $\sum .\left(\sum_{i=0}^{n} .\left(Sub\ criteria.w1\right)\right)w2$

Where,

$$\sum_{i}^{n} = composite\ weights\ from\ i - n\ sub\ criteria$$

w1 is weight of sub criterion
w2 is weight of main criterion

Calculated final composite weights were used to develop suitability criterion such as not suitable, less suitable, moderately suitable and highly suitable. Final suitability map was developed based on the above mentioned different suitability levels.

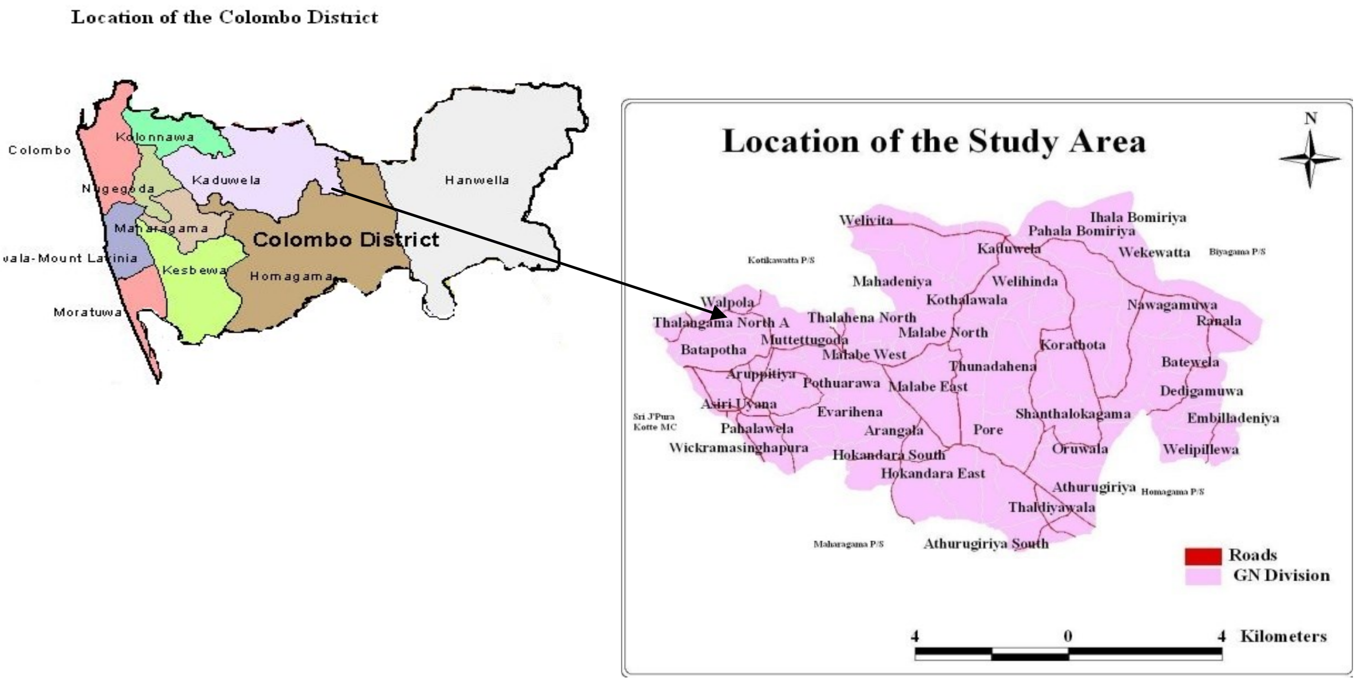
Case Study Area

Kaduwela Municipal Council (KMC) area was selected as the case study area due to high demanded area for residential uses. It is a historically valuable area in the Colombo District and situated 11 Km away from Colombo and 6 Km away from Sri Jayawardenapura Kotte. It comprises of 87.7 Sq. Km (8,770 Ha.) in extent and administratively consists three administrative units. These administrative units are again divided into 57 Grama Niladari Divisions (GND).

Last decade KMC area showed a rapid development of residential uses focused on middle and high income groups. In 1998 residential uses were 50% of the total land use and in 2004 it was increased up to 55% (Urban Development Authority). Locations of main government administrative complexes are one of the main reasons for this high demand. In addition to the above development infrastructure developments are another reason to have a high demand for residential uses in the area. KMC consists of 3 administrative units namely Battaramulla, Kaduwela and Athurugiriya, and Battaramulla is the most prominent area due to being close to the City of Colombo and Sri Jayewardampura Kotte Parliament complex. All administrative complexes are also located in this area. Following figure 1 shows the location of KMC area.

Comparing the population densities in these three administrative units in 2001 Battamulla accounts 40 persons per sq km and others account 20 and 17 persons respectively and Battaramulla is the most populated area compared to the others. The land use pattern of the KMC is more prominent; 55% of the land use consists of residential uses, 19% of the uses are agriculture and 1.8% are bare lands.

Figure 1: Study Area



Analysis

Demarcation of Criterion and Criterion Weights

A sample of a questionnaire survey conducted in KMC and 36 newly developed housing schemes after 2002 were selected for the survey. It consists of 10 housing schemes from Kaduwela unit, 15 from Battarmulla Unit and 11 schemes from Athrugiriya unit. Out of these 36 housing schemes, residents of 180 housing units were interviewed selecting 5 housing units randomly from each scheme. Residents' opinion was evaluated under 6 criterion such as

- population density
- proximity to roads
- proximity to town centre
- proximity to primary & secondary schools
- land value
- land use

Outcome of survey indicated that the highest of the residents in the sample have given their first priority to 3 criterions such as population density, proximity to roads and the proximity to the town centers. Secondly they have given their priority to proximity to the primary and secondary schools, land values and vacant and other land use respectively.

To get experts views 25 experts were selected from different institutions in different professions like town planners, architects, engineers, quantity surveyors, environmentalist, scientists and administrators. Summary of experts views pointed out population density, proximity to roads and proximity to town centers selected to give priority weights. Taking into consideration of those criterions, criterion maps were developed and they are shown in figure 2. The next step is to calculate weights for this criterion maps. Household survey and expert opinion were used to derive weights for each criterion. According to that weights for 6 main criterion and each sub criterion of main criterion were calculated based on AHP method. Following table 2 shows pair wise comparison matrix for 6 main criterion and tables 3- 8 show the pair-wise matrixes for individually main criteria and its sub criterions.

Table 2: Pair-wise Comparison Matrix for Main Suitability Criterion

Category	PD	PR	PT	PS	LV	LU	Weight
Population Density (PD)	1	1	1	2	4	4	0.2500
Proximity to Roads (PR)	1	1	1	2	4	4	0.2500
Proximity to Town Centers (PT)	1	1	1	2	4	4	0.2500
Proximity to Schools (PS)	½	1/2	1/2	1	2	2	0.1250
Land Values (LV)	¼	1/4	1/4	½	1	1	0.0625
Land Use (LU)	¼	1/4	1/4	½	1	1	0.0625

Table 3: Pair-wise Comparison Matrix for Population Density

Category persons per km	0 - 15	15 - 30	30 – 45	45 <	Weight
0-15	1	1/2	1	2	**0.222**
15-30	2	1	2	4	**0.444**
30-45	2	1/2	1	2	**0.222**
45<	1/2	1/4	½	1	**0.112**

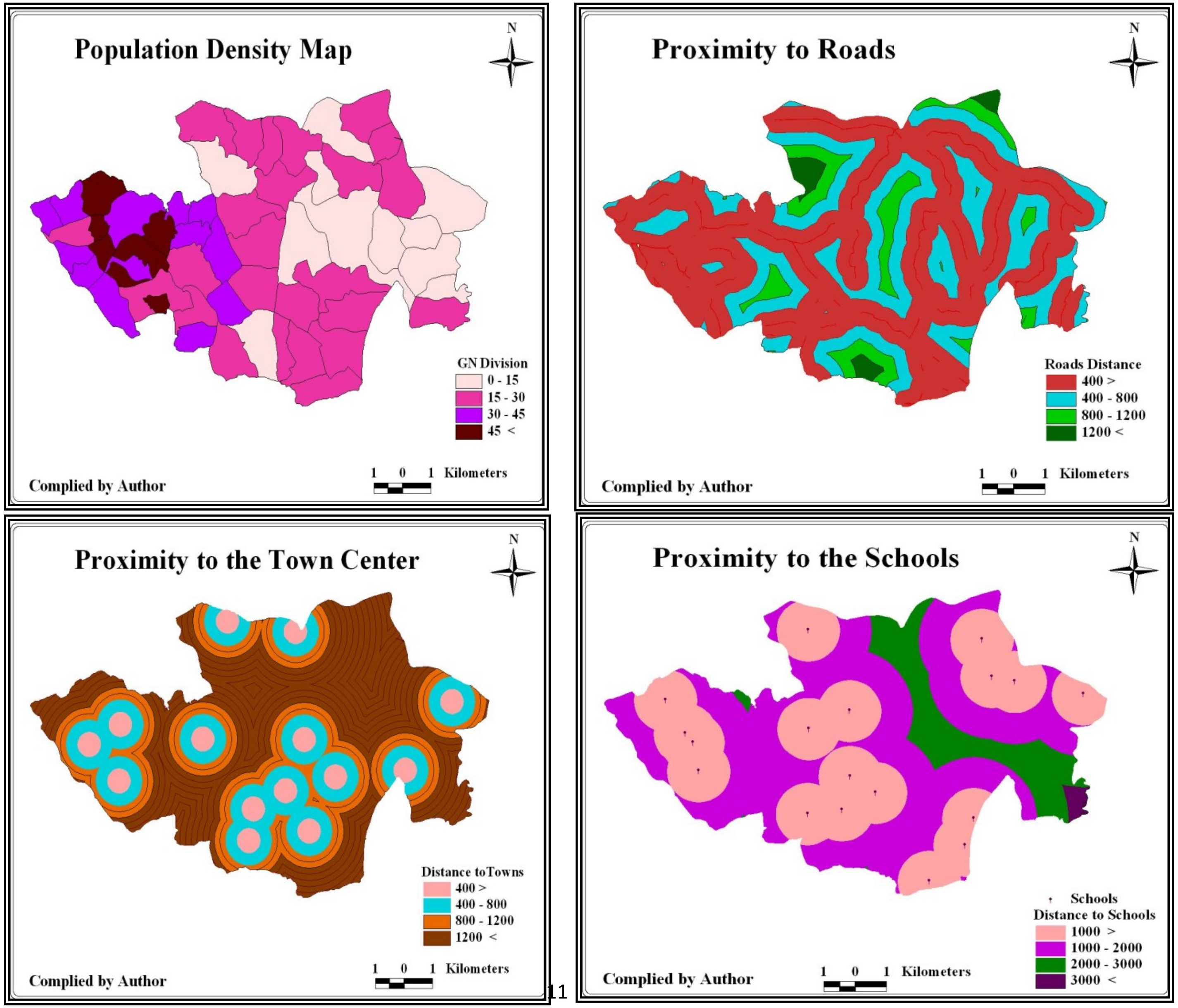
Table 4: Pair-wise Comparison Matrix for Proximity to Roads

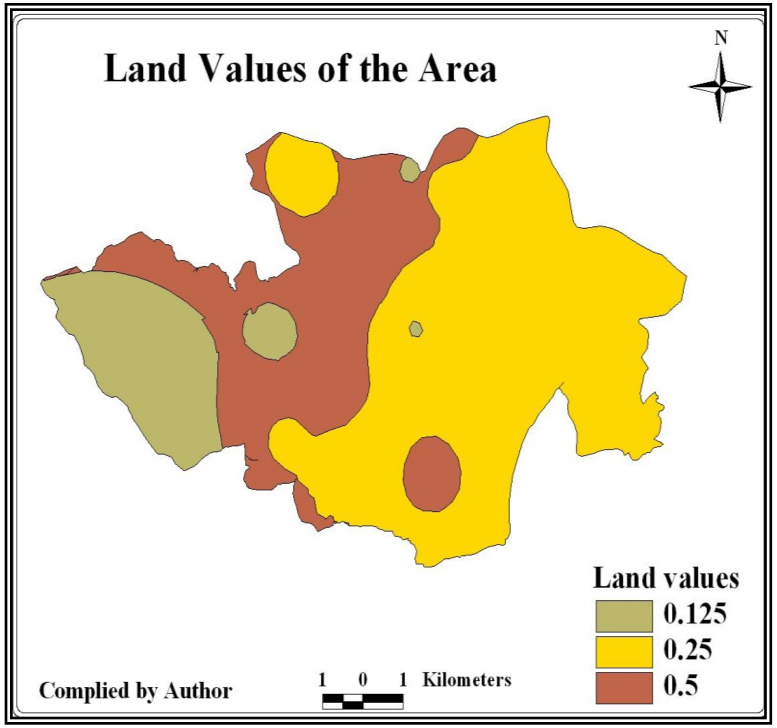
Category distance (m)	< 400	400 - 800	800 – 1200	1200 <	Weight
< 400 m	1	1/2	1	2	**0.222**
400 m - 800 m	2	1	2	4	**0.444**
800 m - 1200 m	1	1/2	1	2	**0.222**
1200 m <	1/2	1/4	½	1	**0.112**

Table 5: Pair-wise Comparison Matrix for Proximity to Town Centers

Category distance (m)	1200 <	800 - 1200	400 - 800	< 400	Weight
1200 m <	1	1	½	2	**0.222**
800 m -1200 m	1	1	½	2	**0.222**
400 m -800 m	2	2	1	4	**0.444**
<400 m	1/2	1/2	¼	1	**0.112**

Figure 2: Criterion Maps




Land Values of the Area
N
Land values
0.125
0.25
0.5
Complied by Author
1 0 1 Kilometers

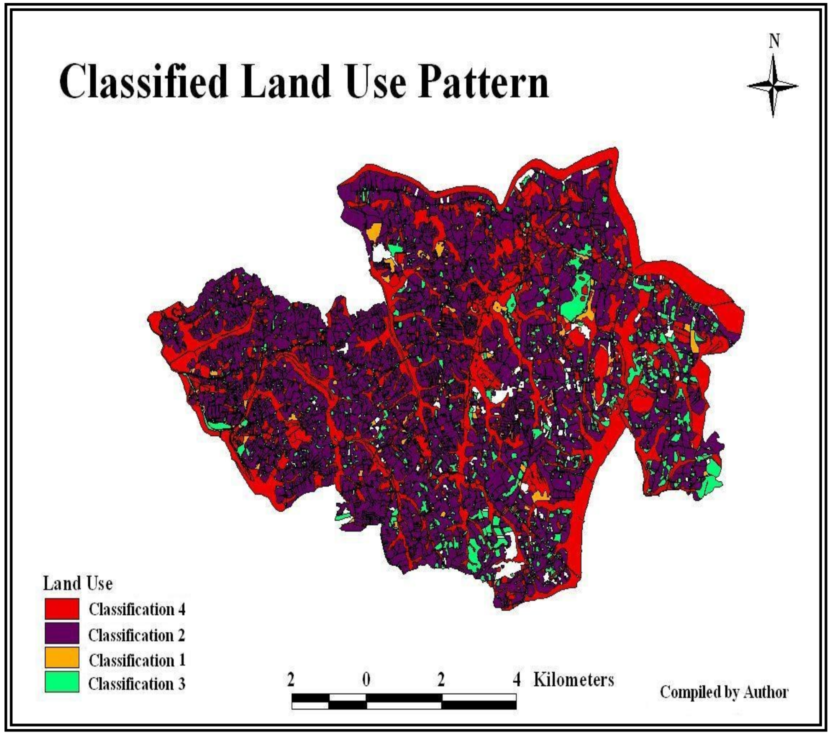

Classified Land Use Pattern
N
Land Use
Classification 4
Classification 2
Classification 1
Classification 3
2 0 2 4 Kilometers
Compiled by Author

Table 6: Pair-wise Comparison Matrix for Proximity to Primary and Secondary Schools

Category Distance(m)	<3000	2000 -3000	1000 -2000	<1000	Weight
< 3000 m	1	1/2	2	2	**0.250**
2000 m -3000 m	2	1	4	4	**0.500**
1000 m -2000 m	1/2	1/4	1	1	**0.125**
< 1000 m	1/2	1/4	1	1	**0.125**

Table 7: Pair-wise Comparison Matrix for Land Values

Category Value per perch(million)	< 0.1 M	0.1M < 0.5 M	0.5 M < 1 M	1M <	Weight
< 100,000	1	1/4	½	1	**0.125**
100,000 < 500,000	4	1	2	4	**0.500**
500,000 < 1,000,000	2	1/2	1	2	**0.250**
1,000,000 <	1	1/4	½	1	**0.125**

Table 8: Pair-wise Comparison Matrix for Land Use

Category	Classification 1	Classification 2	Classification 3	Weight
Classification 1	1	2	4	**0.571**
Classification 2	½	1	2	**0.286**
Classification 3	¼	½	1	**0.143**
Classification 4	0	0	0	**0.000**

It is not possible to derive ranks for the criterion based on weights calculated in pair wise indexes. Therefore composite weights should be calculated. Hence, derived weights of main criterion and sub criterion can be used to calculate composite weights. It uses the formula which was discussed in the methodology. Calculated composite weights are illustrated in table 9.

Suitability Classification

Above calculated composite weights were classified under 4 suitability classifications like not suitable, less suitable, moderately suitable and highly suitable. Table 10 illustrates this classification.

Table 9: Composite Weights for each Criterion

No	Criteria	Weight on each criteria	Sub Criteria	Weight	Composite weight
1	Population Density	0.250	0-15	0.222	0.0555
			15-30	0.444	0.1110
			30-45	0.222	0.0555
			45<	0.112	0.0280
2	Proximity to the Main Roads PRDA Roads	0.250	<400 m	0.222	0.0555
			400 m - 800 m	0.444	0.1110
			800 m - 1200 m	0.222	0.0555
			1200 m <	0.112	0.0280
3	Proximity to the Town center	0.250	1200 m <	0.222	0.0555
			800 m -1200 m	0.222	0.0555

			400 m -800 m	0.444	0.1110
			<400 m	0.112	0.0280
4	Proximity to Primary and Secondary Schools factor	0.125	<3000 m	0.250	0.0313
			2000 m -3000 m	0.500	0.0625
			1000 m -2000 m	0.125	0.0156
			<1000 m	0.125	0.0156
5	Land Values	0.063	< 100,000	0.125	0.0788
			100,000<500,000	0.500	0.3150
			500,000<1,000,000	0.250	0.1575
			1,000,000<	0.125	0.0788
6	Land Uses	0.062	Classification – 1	0.571	0.0354
			Classification – 2	0.286	0.0177
			Classification – 3	0.143	0.0089
			Classification – 4	0.000	0.0000

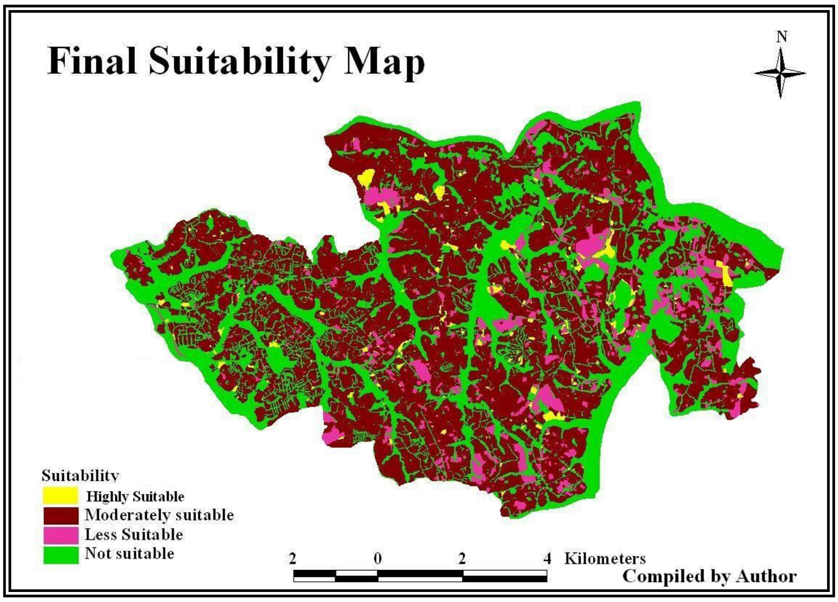
Table 10: Classification of Suitability

Suitability Ratings	Composite Weight Range
Highly Suitable	> 0.0444
Moderately Suitable	>= 0.0444 Comp Weight < 0.0176
Less Suitable	>= 0.0176 Comp Weight < 0.0087
Not Suitable	< 0.0087

Final Suitability Map

Based on the above suitability classification final suitability map was developed and it is shown in the following figure 3.

Figure 3: Final Suitability Map



To validate the results of the suitability, the map was compared with the zoning map in KMC developed by the Urban Development Authority. The planning authority classified the land use zones in to 12 classifications. Out of these 12 zones, 9 zones are allocated for the residential development. But 57% of the lands are suitable for residential development. Hence desired land for residential developments can be demarcated based on that map. The validation process of the suitability map illustrates that all of non-permissible zones for the residential development are located within the not suitable areas of the suitability map. Non permissible zones such as Geological Conservation Zone, Green Zones are located in non-suitable areas of final suitability map.

Hence it can be argued that suitability map identifies most suitable areas for residential development and this scientific calculation tallies with the existing zoning map. But this final map illustrates more than the zoning map, it highlights the most suitable lands within the residential permitted zones. Therefore this final suitability map provides a useful guide for zoning map.

Findings and Discussion

Results of the study indicate highly (2%) and moderately (55%) suitable area consists 57% of the total land in the study area. This indicates that KMC area has the ability to fulfill future demand for residential needs. The most remarkable identification of this analysis is that 2 % of highly suitable lands belong to a vacant land category. It indicates validity of this scientific calculation. Most of the moderately suitable lands are also located in Kaduwela and Athurugiriya Sub Units and these lands are completely located in permissible zone for residential use. It concludes that over 57% of lands available in KMC have potential for residential development.

Most of the less suitable for development category belongs to agricultural area and it is named in the zoning plan under the less suitable category and those are also located in Kaduwela and Athurugiriya Sub Units. Further these lands are also located in permissible zone for residential use, but lack of infrastructure facilities is a barrier for the development. Provision of proper infrastructure developments within these areas therefore will increase of residential use. These lands support to fulfill the residential demand in near future and authorities can further minimize the development by improving agricultural mix of these areas. Not suitable category belongs to the restricted zone for development and these areas can be used for future green development.

This final suitability analysis illustrated areas which are potentials for residential development. When taking the decisions about future residential expansions, these areas can be considered. Therefore this final suitability map can be used as a guide map for zoning. Also KMC will decide to determine the rates based on the "Capital Value"; the land value of the concerned properties can be used in above suitability map. This map when compared with cadastre map, value of each plot of land can be determined.

Conclusion

This research presents a multi criteria framework for suitability analysis of residential development. It considered residents' perspectives and GIS assisted Multi Criteria Evaluation Techniques were used for the analysis. The suitability analysis has been carried out for KMC to evaluate feasibility of existing residential use and potential lands without considering the social, environmental and economical constraints as evaluation parameters. The suitability analysis was done in the area using the frame -work with a number of criteria relating to residential development and their priorities elicited from local residents. The above scientific classification used is in line with the zoning plan of the study area and it can be used as a guide map to the zoning plan of the study area. Final map shows suitability locations and it shows in depth picture to zoning plan. Therefore the findings of the research will be beneficial to various parties. Many stakeholders are trying to understand the nature of residential property market that follows the property development. This will be useful for the people who are looking for the suitable and profitable places to purchase the residential properties and to identify the development level of the area.

References

a) *Al-shalabi Mohamed Shattri A., Mansor Bin, Ahmed Nordin Bin, Rashid Shiriff, "GIS Based Multi-Criteria Approaches to Housing Site Suitability Assessment".*
b) *Banai R, (1993), "Fuzziness in Geographic Information Systems: contributions from the Analytic Hierarchy Process", International Journal of Geographic Information Systems, Volume 7.*
c) *Fang Da and Liu Guolin (2004). "The research on the GIS-based land suitability evaluation", Geometrics and Spatial Information Technology, pp: 35-37*
d) *FAO (1976) "A Framework For Land Evaluation", Soils Bulletin No. 32, Rome.*
e) *Joerin Florent, "Using GIS and outranking multi criteria analysis for land-use".*
f) *Kaiser Edward J, David R, Chalk God S and Stuart F , Chapin J R , (1995) "Urban Land Use Planning", 4th Edition, University of Illinois , United states of America .*
g) *Kaiser et, al. (1995), "Urban Land Use Planning". Forth edition, University of illinos, U.S.A.*
h) *Laaribi, A., Chevallier, J., & Martel, J. (1996). "Spatial decision aid: a multicriterion evaluation approach.Computers, Environment and Urban Systems", (1998).*
i) *Lean Mc (1988}, "EXPERT CHOICE" Decision Support Software, Inc, Virginia.*
j) *Madurapperuma,S. (2005) "Migration, Urbanization, Industrialization, Export Promotion and Economic Development Census of Population and Housing 2001", Sri Lanka, Graduate School of Economics , Ritsumeikan University, Japan.*
k) *Malczewski Jacek, "GIS-based land-use suitability analysis: a critical Overview", Department of Geography, University of Western Ontario, London, Ont., Canada.*
l) *Manlum Yang, (2003), "Suitability Analysis for Urban Green Space System based on GIS", Inter National institute for Geo Information Science & Earth Observation, Enchede, and The Netherlands.*
m) *Manso Shattri Bin r, Nordin Bin Ahmed, Rashid Shiriff, Mohamed A. Al-Shalabi, (2006). "GIS Based Multi Criteria Approaches to Housing Site Suitability Assessment".*
n) *Matthew L. Clark, (2007), "Land Use Suitability Analysis for the Gravenstein Highway Corridor Study Plan", Dept. of Geography and Global Studies, Sonoma State University.*
o) *McDonald, G. T., Brown, A.L., 1984. "The Land suitability approach to strategic land-use planning in urban fringe areas. Landscape Planning" 11 (1984), pp:125-150*
p) *Meron Tariku Ayne, (2007), "Surface irrigation suitability analysis of Southern Abbey basin by implementing GIS Techniques" ,A case study in Dedessa sub-basin, University technology faculty.*
q) *Olaniyi Saheed S., Udoh Ekanem, Oyedare Benjamin A., "Application of GIS in Estate Management" A Case study of Araromi Phase,Nigeria.*
r) *Openshaw, S. and Abrahart, R., (2000). "Geo Computation". Taylor & Francis, London.*
s) *Pacione Michel (2005), "Urban Geography", 2nd edition, University of Strathclyde in Glassgo.*
t) *Parnwell M (1993) "Population movements in the third world" London, Rutledge.*
u) *Maguire D J (1991), "An overview and definition of GIS", Volume 1, London.*
v) *Pavasoviæ S lobodan, "GIS Tool for Site Suitability Analysis: Example of Marine Aquaculture", Faculty of Civil Engineering and Architecture, Matice hrvatske, Croatia.*

w) *Pease, Coughlin (1996), "Land Elevation and Site Assessment". A guide book for Rating Agricultural Lands. Ankeney IO soil and Water conservation Society.*
x) *Pettit C , Pullar D, "An integrated planning tool based upon Multiple Criteria Evaluation of spatial information", Australian Housing and Urban Research Institute, Department of Geographical Sciences and Planning, University of Queensland, Queen St. Lucia, Queensland, Australia.*
y) *Pooley C (1979) , "Residential Mobility in the city" Transactions of the institute of British Geographers ,Decision Making, Department of Geography, University of Toronto.*
z) *Hachadoorian, "Location Theory", Geog 221—Economic Geography.*
aa) *Ping Ai, (2005 March),* ***"****Residential land value modeling"***,** *Case study of Hankou, China.*
bb) *Rinner C, Taranu J, (2001), "A Geographic Visualization Approach to Multi Criteria Evaluation"*
cc) *Ross P , (1995), "why Families Move" , New York Free press.*
dd) *Rossiter, David G. 1996. A theoretical framework for land evaluation. Geoderma 72 (1996), pp165-190*
ee) *Saaty, T.L., {2000) "Fundamentals of decision making and priority theory with the Analytic Hierarchy Process", Volume 6. RWS Publications, Pittsburgh, PA.*
ff) *Saaty, T. L (1980). "The Analytical Hierarchical Process". Planning, priority setting, resource allocation. New York, McGraw-Hill, New York.*
gg) *Salem Chakhar, Vincent Mousseau, "Multicriteria Spatial Decision Support Systems", Lamsade University of Paris Dauphine, France.*
hh) *Shuaib Lwasa, "A Geo-Information Approach for Urban Land Use Planning in Kampala Shuaib LWASA, Uganda", Department of Geography Makerere University.*
ii) *Shidai Wu, (2000). "GIS aided Land suitability appraisal for a multi-objective land-use in Fuqing Municipality". Journal of Fujian Teachers University, China. pp: 87-90.*
jj) *Spring, (1997) "An Introduction to GIS using Arc View, A Tutorial based on Arc View release 3.*
kk) *Steiner Frederick, (1991). "A method applied to a case study of growth management, Environmental Management", Landscape Planning, pp: 519-529*
ll) *Steiner F, McSherry L, (2000). "Land suitability analysis for the upper Gila River watershed". Landscape and Urban Planning, pp 199-214.*
mm) *Sui Daniel Z. , "GIS-based urban modeling, practices, problems, and prospects", Department of Geography, Texas A & M University, College Station, USA.*
nn) *Tran Trong Duc , "Using GIS And AHP Technique For Land-Use Suitability Analysis" , Department of Geomatics, Polytechnic University of Hochiminh city, Vietnam.*
oo) *Weerakoon K.G.P.K., "Integration of GIS based suitability analysis and multi criteria evaluation for urban land use planning; contribution from the Analytic Hierarchy Process", Senior Lecturer, Department of Estate Management and Valuation, University of Sri Jayewardenepura , Nugegoda, Sri Lanka.*
pp) *Wu Qiang and Chen Ping, 2000. "The agricultural land suitability assessment based on GIS". Geotechnical, 2000, No.4, pp: 47-51.*
qq) *Wu Shidai, 2000. "GIS aided Land suitability appraisal for a multi-objective land-use in Fuqing Municipality". Journal of Fujian Teachers University 16, No3. pp: 87-90 (in Chinese)*
rr) *Yeung H Wai- Chung (1997), "Critical Realism and Realist Research in Human Geography; A method or philosophy in search of a method progress in human Geography".*
ss) *Zhu Xuan, Monash, Liu Suxia, Yeow Mun-Ching, "Accessibility Analysis for Housing Development in Singapore with GIS and Multi-Criteria Analysis Methods" National Institute of Education, Singapore University, Australia.*
tt) *Zhu X, Liu S and Yeow M C, (2002), "GIS based MCA Approach to accessibility Analysis for Housing Development in Singapore", School of Geography and Environmental Science, University of Monash , Elburn .*