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SITE SUITABILITY ANALYSIS FOR A SATELLITE TOWN OF KHULNA CITY USING GIS: A CASE STUDY

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Abstract: A suitable site for a satellite town must have required criteria's or involved facilities and attributes that will enable the town to be isolated so that there is no unacceptable lack to the city people it is operating. Criteria for site selection of a satellite town include natural physical characteristics as well as socioeconomic, land-use and ecological factors. Optimum land utilization of human being includes the survivality and sustainable development. Therefore, site suitability of is a prerequisite domain of inquiry, which could facilitate the process of decision making as the suitability of the land for its moist beneficial use. This study is designed to carry out a site suitability analysis for the establishment of a satellite town in Khulna City area. It is also assumed that it is possible to interpret environmental data to determine such suitability based on specific environment and other objectives, standard and design principles. GIS techniques were put into use for virtually all-environmental analysis, are also employed for this work at different stages.

Key words: Site suitability, satellite town, GIS, DSS and ESS

Introduction

Khulna, a like most city of the developing world is a poorly managed city, which leads to deteriorate of urban living conditions. Urban poverty results in many countries, due to lack of national and local governments plan for the increased population, and fails to provide the required infrastructure, services and jobs. Government efforts through all these years to provide housing to government servants, to the general public and to the urban poor have not so far been able to make any significant dent in the urban housing scene (Mamun, 2002). The government is the single largest provider of built up housing in Bangladesh mainly in the form of accommodation for its employees. Although the number of units provided is far less than the number of employees, government housing continues to be a strong influence on urban housing in general. The trends established by government housing are followed by other semi-government agencies and to a large extent by private developers. The formal planned developments also influence the unplanned settlements (Mamun, 2002). Government housing can therefore be said to be representational of urban housing in general. So in bringing out the problem related to strategies of the project, the intention is that the efforts in future can be made more meaningful and effective. A suitable site must have some criteria's and attributes that will enable the location to be fully served, safe and

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sustainable so that there is no unacceptable risk to people or the environment (Manoliadis *et al.,* 2002). Criteria for site selection include natural physical characteristics as well as socioeconomic, ecological and land-use factors. The Geographical Information System (GIS) can provide an opportunity to integrate field parameters with population and other relevant data or other associated features, which help in selection of sites (Sharif, 1995). Site selection procedures can benefit from the appropriate use of GIS. The use of GIS in selection process will reduce the time and enhance the accuracy (Lombaridi *et al.,* 1996). The slow growth of housing in Khulna city is reflected in its cost of living index of the citizens in general and highly skewed distribution of income against a large number of poor people in the city. Moreover, they (public and private) are trying to meet the demand of housing. However, the private initiative is very little in quantity. Among all initiatives, public sector share is dominant.

The prime objectives are: (i) To solve the housing problem as well as give the idea of further development; (ii) To estimate the additional requirement of area suitable for future development; and (iii) To identify the area suitable for development with the help of the land analysis to meet the demand for future.

Materials and Methods

Discrete selection of the study area is very much momentous for any study. It is remarkable that the ultimately success of any research work fully depends on the selection of the study area. Since Khulna city is the third largest city of Bangladesh and it is rapidly urbanizing. About 69.5% of Khulna City population consists of lower income group, 29.7% belongs to middle income and only 1.8% is of upper-income group (BBS, 2001). Present area under its jurisdiction is 44.78 square kilometer divided into 31 wards with population about 1300000. Common benefits of GIS include its ability to: (i) capture, store, and manage spatially referenced data, (ii) provide massive amounts of spatially referenced input data and perform analysis of the data, (iii) perform sensitivity and optimization analysis easily, and (iv) communicate model results (Miles *et al.,* 1999; Parsons *et al.,* 2000). Spatial feature extraction or classification is one of the GIS capabilities for searching suitable sites .The ultimate aim of Geographical Information System is to support spatial decision making. Spatial decision-making process has been structured into three major phases: Intelligence, Design and Choice as shown in Fig. 1 below. Intelligence phase refers to the recognition of decision problem. It is a gap between desired and existing states or an opportunity for change (Leondes, 2000). During this phase raw data are obtained and processed to convert the real world decision situation into GIS database and consequently examined for clues that nay identify opportunities or problems. It is argued that adequate support for intelligence phase of decision-making is provided by current GIS systems (Rahman *et al.,* 2004).

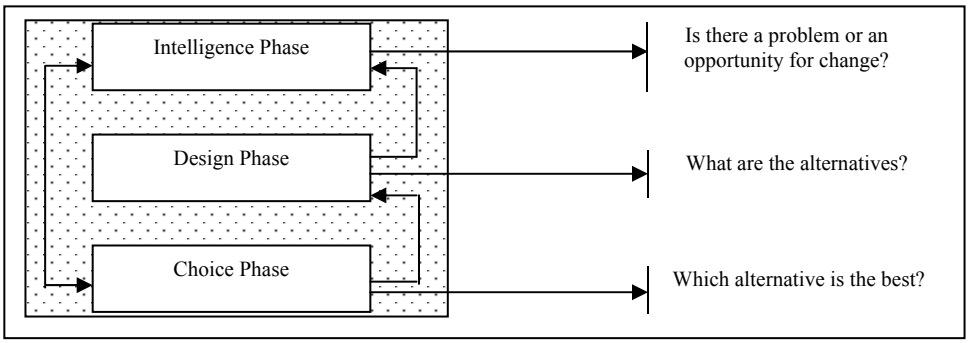


Fig. 1. Three phase of decision-making process (Rahman *et al.,* 2004).

The design phase involves inventing, developing and analyzing a set of possible solutions (alternative course of action) to identify in the intelligence phase. Typically a formal model representing the abstraction of

reality is used to support a decision maker in determining the set of alternatives (Saini, 1987). The generation of alternative decisions is purely a part of the design stage and the evaluation of alternatives is mainly the part of choice phase. The choice phase is how many people are involved in making a decision. It involves selecting a particular course of action (alternatives) from those available. At this phase each alternatives is evaluated and analyzed in relation to others in terms of a specified decision rule (Rahman *et al.,* 2004). Decision-making is a process and it involves a sequence of activities that starts with decision problem recognition and ends with recommendations (Rahman *et al.,* 2002). It is argued that quality of decision-making depends on sequence in which the activities are undertaken. Any decision-making process is composed of three major phases are (i) Intelligence, (ii) Design, and (iii) Choice. As such methodology of the present study of spatial decision-making process of suitable sites for satellite town will be discussed according to the three-phase decision making process.

Intelligence phase: Intelligence phase involves searching or scanning the decision environment for conditions calling for decisions. The data acquisition, storage, retrieval and management functions convert the real world situation into GIS database during this phase. This involves assumptions or views of the world underlying a particular decision problem. The assumptions are concerned with the following questions, which of the real world entities should be observed, selected, filtered, classified and recorded as data items and which items are relevant to subsequent spatial decision problem? Coordination must be given to the usefulness, accuracy, reliability and flexibility of data. Once spatial decisions are identified the data can be manipulated and analyzed to obtain information about the decision problem in hand. With this view in mind various thematic maps have been prepared for their integrated in Geographic Information System (GIS) base (Rahman *et al.,* 2002).

Design phase: Design phase involves inventing and analyzing a set of possible solutions to identify the problem in the intelligence phase. Here in case of site suitability analysis for urban development. What are the spatial decisions criteria or decision rules we have to consider in locating those suitable sites? So design phase represents the decision situation by structuring and formalizing the available data and information about the decision problem. Spatial decision alternatives are derived by manipulation and analysis of the data and information stored in GIS. As our ultimate aim is to use Spatial Expert Support System (SESS) for the purpose of decision making, it will be better to look into available guidelines and experts opinion at this design phase which will help us in creating rule based decision trees or knowledge base in Expert Classifier shell of the software used in this present study.

Existing Housing Conditions in the Study Area and need for Satellite Town: Town, name applied generally throughout the small municipalities, larger than the village and smaller than the city or county. The town is usually operated under its own powers of local government granted by the state government. The town concepts began in the 1960s many towns began providing for an appointed official to be responsible for overall administrative affairs, an arrangement similar to the council-manager concept. Satellite town mean the town containing all the facilities of a model town, installed in accordance with the crying needs or demands of existing one. Besides these, a number of housing problems have been identified by the household survey of the study team in the KCC area. Among these problems, at least three should be mentioned here due to their relevance in structure planning. First, the problem of owning house due mainly to low levels of income in the one hand and lack of credit facilities on the other. Second, the location problems, as a substantial proportion of households indicated that it was not very convenient to go to the work places from their respective homes. And third was the poor living environment due to lack of necessary social services. The rented households are the large in numbers (43%) in the Khulna City. Only 27% household has his own house. There are 1, 87,195 housing units in the KCC area. If the corresponding number of households during the same period were compared, there were shortages of 12,358 housing units 6.6%. In the KCC area, such shortages of housing are 8%. This gives marginal shortages of housing units in Khulna, which is 7%. In other words, about 7% of the households in Khulna do not have proper housing. In urban areas of Bangladesh, there were shortages of 800,000 housing units in 1991, which means nearly 20% of urban households were not properly housed. Thus, compared with the national situation, Khulna seems to be comparatively in a better condition. The old residential areas, characterized by one and two storied structures of bricks and steel truss roofs, still shows reasonably good and most houses are well maintained. Semi-urban settlements are common along the either side of the rivers *Bhairab* and *Rupsha*, and Khulna-Jessore railway line and road, except in the older part of the city. These settlements are characterized by low net density in terms of both

housing as well as population. Housing structures are predominantly *katcha*, but a good proportion of *pucca* and semi-*pucca* houses are also found in these areas. These settlements are predominantly occupied by the native inhabitants. The southern part of the city, where main residential areas have been developed, is characterized by such spontaneous housing development. The southern part of the city developed as residential zone where old residential areas like *Toot Para*, *Rai Para*, and *Musalman Para* are situated. Side by side new residential areas developed in *Bagmara*, BK Road, East *Baniakhamar*. West *Baniakhamar*, *Banarganti* and *Gobor Chaka* are old residential areas in the southwestern part. Residential areas in *Daulatpur* and *Moheswarpasha* are also old residential areas. Due to the availability of services, facilities, infrastructure and comparatively better land, expansion of the city is faster towards southwest, where new residential areas both by KDA and general public were developed. However, KDA and HSD also developed a few residential areas in the central part like *Shonadanga*, *Mujgunni*, *Boyra* and *Khalishpur*. However, mainly, due to non-availability of adequate services, low density of population prevails in most of these areas. The housing areas are characterized both by low and high density, depending on location and area. Except around the central city most of the residential areas have vacant land, water bodies and non-residential usage. In most cases, the residential areas are of mixed type housing: squatter/slum houses and modern buildings side by side. The condition of services and amenities are also not satisfactory in most areas. Drainage and road network is found to be inadequate. Agricultural use of land in many residential areas is common in Khulna. The above characteristics of the major residential areas in Khulna indicate that there has been little planning control in housing, except in a few planned residential areas. Planned residential areas in the city are of two categories: a) public sector sponsored site and services projects, and b) apartment based staff housing of public sector agencies. The development of sites and services schemes in Khulna is quite remarkable. Although the plots were allotted in the housing estates long ago the growth of structures and development is rather slow, particularly in low-income housing areas such as *Boyra*. Lack of affordability, low demand for *pucca* housing, absence of HBFC loan are perhaps the major reasons for non-construction of structures in these areas. Situation in high-income areas like *Shonadanga* and *Nirala* is comparatively better. The major staff housing areas belongs to important local and national level agencies. The staff housing areas is mostly provided with all necessary utility and service facilities. The emerging third category is the private formal sector development. At the moment, there are several sites and services schemes are being promoted. However, the real estate authorities have little coordination with city development authority, KDA. In Khulna City Area, there were 150,000 households according to the census of 2001. The dwelling units in the same year were 106,700. Thus, there was a housing backlog of 8300 units. In 1998, considering 3.3 % annual rate of growth in population estimate that at present (1998) there will be 1,44,700 households with 1,29,300 dwelling units. The present backlog is about 15,000. Considering this trend in the growth of households and backlog have been calculated the requirement of housing units for the year 2000, 2005, 2010, 2015 and 2020 (Table 1). It should be mentioned here that have also considered 20 percent replacement of existing housing units per year throughout the period.

Table 1. Housing needs in the KCC area 2000-2020.

Year	House-holds	Growth rate	Dwelling unit		Backlog	Replac ement	Total need
		Percent/year	Percent/year				
1961	24535		21386		3149	837	
1974	80629	9.15	63384	8.36	17245	2481	61724
1979	87202	1.57	86531	6.23	671	3387	27205
1991	114918	2.30	106739	1.75	8179	4178	32565
1998	144781	3.30	129397	2.75	15384	5065	43107
2000	156213	3.80	138087	3.25	18126	5405	32221
2005	193683	4.30	166565	3.75	27118	6519	62115
2010	246219	4.80	206002	4.25	40217	8063	87717
2015	305278	4.30	248486	3.75	56792	9726	109002
2020	369157	3.80	292331	3.25	76826	11442	1,32,113

Source**:** Khulna Development Authority, 2001.

Analysis

The success of any Geographic analysis using GIS depends upon completion of the database used to perform analysis (Rahman *et al.,* 2002). Different spatial and non-spatial information has been required for this study (land elevation, soil, drainage road, population, land use etc.). Some of these have collected as hardcopy. The collected data have processed through different software's and techniques to be converted in suitable form for using in this study. One of the major capabilities of a GIS is that can be analyzed and also different types of data can be integrated. The spatial data refers to data obtained from map data with land use; road network etc,

and attribute data consist of numerical. GIS can carry multiple data sets merging operation and evaluate relationship among chosen element of data in the different layers of data sets under consideration. (Rahman *et al.,* 2004)

Land elevation and soil characteristics: The area comprises a flat land with two natural ground slopes in the study area. One of the natural ground slopes is found from north west to south west, which follows the general flow direction of the *Bhairab* river (upper reach) and *Rupsha* river (Lower Reach). Another natural ground slope follows the northwest to southwest direction from the *Bhairab* and *Rupsha* riverbank towards *Dumuria*. As a result the elevated land lies along the bank of river and low lands are present in the southwestern part of the study area. The general ground elevation of Khulna City Corporation (KCC) and its adjoining area varies from 2.64m in *Dumuria* to 4.07m in *Terakheda* above AMSL (Average Mean Sea Level). Most of the KCC areas are above 3.32 m from AMSL. (Rahman *et al.*, 2002). The elevated land classes are Upland 434 km^2, Moderately Upland 1182 sq. km, Moderately Low Land 718 sq. km. The Land Characteristics of the spatial distribution of the different land Characteristics and the area under different land characteristics are Ganga Polol 315 sq. km, Ganga Katal Polol 107 sq. km, Mixed Ganga Katal 1071 sq. km, Beel area with organic soil 756 sq. km, Home Stead 4287 sq. km, River 472 sq. km. The different land classes of uncultivated area are Ganga Polol 32 sq. km, Ganga Katal Polol 05 sq. km, Mixed Ganga Katal 54 sq. km, Beel area with organic soil 38 sq. km, Home Stead 4073 sq. km, River 477 sq. km. The different Soil Group in KCC area are Gopalpur 283 sq. km, Zhalokathi 289 sq. km, Barishal 838 sq. km, Harta 409 sq. km, Satla 265 sq. km, Vitimati 214 sq. km. Information on land cover, especially the extent and spatial distribution, is a prerequisite for the site suitability for urban development. The land cover information helps in the formulation of policies and programs for urban development. Therefore, an attempt has been made to adopt a suitable land cover classification system for use with available data. The Table 8 showing the different land surface covers information. The different Land Surface Cover is Terrestrial 6402 sq. km, Beel Area 756 sq. km, Mixed (*Terrestrial* and *Beel*) 1,178 km^2 (Yearly report of Khulna Soil Research Institute, 2002).

Drainage system*:* The household survey conducted by Khulna City Master Plan Project reveals that about 15% of the city households have no drainage in and around their premises. About 85% enjoy some sort of drainage facilities. The existing drainage system in the city comprises are *kutcha* (un lined); *pucca* (lined) and, *Semi-pucca* system. According to KCC sources, the total length of various types of existing drains is about 381 kilometres. All drains fall into the nearby rivers, *khals* e.g. the *Bhairab*, the *Rupsha* and the *Hatiya* river. The most areas of Khulna city is generally above the normal flood level, hence free of direct flooding from the *Bhairab-Rupsha* river system. However, the low-lying areas on the southern part of the city are subject to occasional flooding by tidal water during monsoon. Embankments around the city protect it from river flooding. There are six regulators and eight sluice gates to drain out excess water from the city area.

Road network: KCC area is served by a network of *pucca* (metalled), *semi-pucca* and *katcha* (unmetalled) roads. Total road mileage in KCC area is about 327.21kms of which 168.88 km are *pucca*, 101.52 km are semi-*pucca* and the remaining 56.81kms are *kutcha*. Most of the KCC roads are in good condition except those which are *kutcha* and *semi-pucca*. The single lane *pucca* roads are narrow, often 3.6 m in width, with un-surfaced *kutcha* shoulders and insufficient or no space for parking and pedestrian movement. Open roadside drain creates environmental problems for pedestrians.

Population distribution: The present average density of population of Khulna city stands at 17,735 persons per sq.km. The highest density wards are 10, 11, 12 and 20 where density varies between 45,152 to 53,335 persons per sq.km. Ward No. 10, 11 and 12 are the high-density wards of the city all of which are in *Khalishpur* planned residential area close to the industrial area. Ward No. 20 is situated in the old part of the city and is a spontaneously grown area. The lowest density wards fall in the northwestern fringe where the structures are sparsely built and dominated by huge vacant and agricultural land.

Vacant Land: Any new urban use needs the supply of vacant land in this point of view, the term ‘vacant land ‘can be define as the land , which is needed for any use in the space requirement process of land use planning .The agricultural land in KCC are has been identified as vacant land in this study. the amount of these lands in KCC is 2451.401acres. Besides these lands, railway vacant land is also considered. Ward 9,3,and 31 have the most of this vacant land .Ward 9 has the sufficient vacant land. There are 16 wards having the vacant land in KCC. Others wards are not having any vacant lands and so those wards are excluded such as ward no 1

(48.266 acres), 3 (336.158 acres), 4 (96.49 acres), 5 (9.014acres), 6 (33.759 acres), 9 (750.730 acres), 14 (244.197 acres), 16 (168.981 acres), 17 (155.616 acres), 18 (211.549 acres), 19 (0.169 acres), 21 (0.197 acres), 24 (48.805 acres), 25 (0.002 acres), 27 (9.073 acres), 31 (338.396 acres).

Land use pattern: As mentioned earlier, because of physiographic setting, Khulna has grown along the west bank of the river *Bhairab* in a linear pattern. Because of the non-availability of buildable land on the west, the westward growth of the city has been restricted, making the city a narrow strip of urbanized land, 16 km in north-south and a maximum of 4 km in east-west. The settlement area with 23.50 sq km. (51.1% of the city area) dominant among the land use categories. The mixed built-up area (residential area with intense commercial activity) 14.3% of the total city area, spread over the older areas (ward nos. 20, 21, 23, 26, 27, 19) of the city. It is notable that 21.2% of the city corporation area is in agricultural use, which lies along the western fringe of the city. The land use pattern in Khulna city are settlement area 23.50 sq km, Agricultural land 9.77 sq km, Mixed built up area 6.58 sq km, Industrial area 3.07 sq km, Commercial area 0.48 sq km, Education 0.35 sq km, Railway property 0.32 sq km, Shipyard 0.32 sq km, Government institutions 0.13 sq km, Low land 0.13 sq km, Grave yard 0.07 sq km and Others 1.28 sq km (Source: KDA, 2001).

Results

The study was conducted for identification of suitable sites for satellite town considering some factors as well as land use pattern, road system, soil depth and land characteristics, educational facilities, etc. in KCC area. To gain the prime objectives of this research work the suitability of the sites are classified on the basis of different criteria .As for example the classes are (i) Very Suitable, (ii) Suitable, (iii) Moderately Suitable, (iv) Less Suitable, and (v) Unsuitable. On the basis of suitability analysis rules the following decisions have been formed.

Table 2. Decision Rules for selecting the Suitability site for satellite town.

Land use	Land characteristics	Soil	Drainage/ Ground water	Vacant land	Road network	Population density	Suitability class
Vacant /Barren	Upland	Goplapur, Vitamati	Good	More than 500 acres	500m buffer	Less	Very suitable
Agricultural	Moderately upland	Zhalokhati	Very good to moderate	400-500 acres	400m buffer	Moderate	Suitable
Slums	Plain land	Barishal	Moderate	200-400 acres	300m buffer	Moderately high	Moderately suitable
Mixed built up area (village, unplanned residential area)	Moderately low land	Harta	Poor	1-200 acres	100m buffer	High	Less suitable
Others (institution, commercials area, water bodies, etc.)	Low land	Satla	other	Less than 01 acres	50 buffer	Very high	Unsuitable

Very suitable site*:* The sites considered as suitable for satellite town if it satisfy all the criteria (shown in Table 2) as distant 500m from main road, very good deep water supply, less population density, away from hotel, market and shopping centers etc. and proper recreational facility. The site is very suitable for many purpose educational institute are near to the satellite town, health facilities are available here. For gaining high suitability the sites had to also satisfy the land elevation or contour, soil type, land use criteria, specifically which are considered in selecting the sites. And obviously the site plotted in low dense area.

Suitable site: The sites considered as moderate for satellite town if it satisfy all the criteria of moderately suitable column of Table 2 as distant 400 m from main road, moderate drinking water

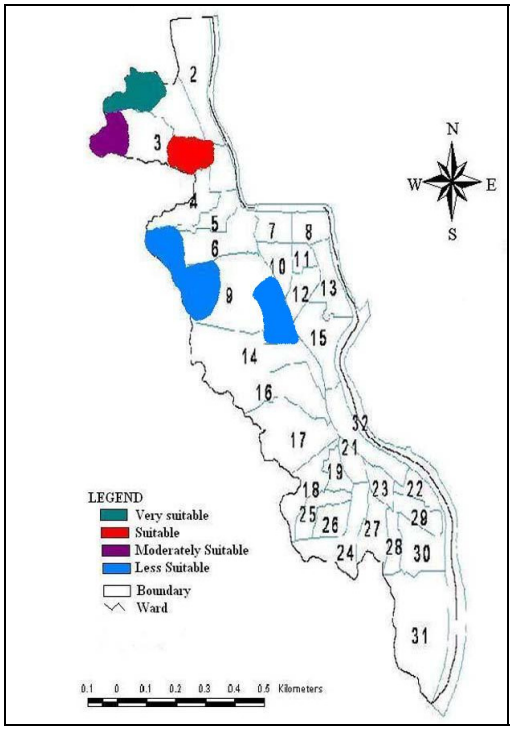
supply, and moderate population density. The site is suitable for many purpose educational institute are near to the satellite town, health facilities are available here. This site is not very suitable because the main road is beside the town and various kind of pollution (noise, air etc.) harmful for human health.

Moderately suitable site: The sites considered as less suitable for satellite town if it satisfy all the criteria of less suitable column of Table 2 as distant 300 m from main road, moderate drinking water supply, and moderately high population density. The site is less suitable because the educational institutes are near to the satellite town; the noise pollution is high here. The site is highly commercial area, which are the main obstacles for satellite town.

Less suitable site: The sites considered as less suitable for satellite town if it satisfy all the criteria of less suitable column of Table 2 as distant 100 m from main road, poor drinking water supply, and population density is very much low here. This site is not suitable for satellite town because the people of this area are culturing shrimp in this land.

Unsuitable Site: The sites considered as less suitable for satellite town if it satisfy all the criteria of less suitable column of Table 2 as distant 50 m from main road, poor drinking water supply. This site is not suitable for satellite town because these areas are high population dense. Over 1000 m from the main road and these areas are suitable for shrimp culture. For the water body over 1000 m areas are not suitable for satellite town.

Selection of suitable sites: Five sites have been located by the multi criteria evaluation method which is shown in Map 1. In this map one very suitable site, one suitable, one moderately suitable and two less suitable sites are shown.



Map 1. Suitability map of the study area.

Conclusion

This study used GIS integrated standard methodology for the selection of sites, which are suitable for satellite town in KCC area. This methodology incorporates a large number of environmental and economic factors which are essential to identify the sites which have no or minimum adverse impact on environment. In fact, many other parameters are required for this study, but the most important parameters have been taken into consideration. The study illustrates the importance of GIS technology in the present days. GIS technology, as an information tool, has helped in the acquisition of recent land use information studies aimed at solving environmental problems. Information on different aspects for this study like land use, road, population density and slope etc., has been derived using this technique. Further integrating this data using GIS has helped in the analysis of the study, which would have otherwise been difficult to do manually using the conventional method. The process is not only faster but can be very effective in the eventuality.

Adequate attention was taken for data management to ensure the perfection of the decision based on the methodology. Though GIS based methodology is highly sophisticated or developed or standard one but its success depend on the proper and careful application. To carry out the result GIS tools were used carefully in every stages of the methodology.

References

Anon. 2001. *Population Census*. Vol. 01, Bangladesh Bureau of Statistics, GOB, Dhaka, Bangladesh.

Anon. 2001. Structure plan, master plan and detailed area plan for Khulna city 2001, Vol. II, Khulna Development Authority, pp. 132, 174.

Leondes, T.C. 2000. Knowledge Based System: Techniques and Application, Academic press, New York, pp. 189-250.

Lombardi, M., and Bellorini, N. 1996. Information and Decision Support System with GIS Technology: Landfill Siting in Botkyrka. Unpublished M.Sc. thesis, Royal Institute of Technology, London, pp. 89-115.

Mamun, R. 2002. Housing at Uttara model town in Dhaka city, Bangladesh, Unpublished report, University of Engineering and Technology (BUET), Dhaka, Bangladesh, pp. 5-70

Manoliadis O. and Vatalis, K. 2002. A two-level multicriteria DSS for landfill site selection using GIS: Case study in western Macedonia. *Journal of Geographic Information and Decision Analysis,* 6(1): 49-56.

Miles, S.B. and Ho, C.L. 1999. Applications and issues of GIS as tool for civil engineering modeling, *Journal of Comparative City Engineering,* ASCE, 13(3): 144-152.

Parsons, R.L. and Frost, J.D. 2000. Interactive analysis of spatial subsurface data using GIS based tool, *Journal of Comparative City Engineering,* ASCE, 14(4): 215-222.

Rahman, M.M. and Subudhi, A.P. 2002. Site suitability analysis for satellite town of Chandigarh, India. *Plan Plus,* 1(1): 16-28.

Rahman, M.M. and Subudhi, A.P. 2004. Knowledge based spatial expert support system in identifying suitable sites for urban development in Dheradhun city, India. *Plan Plus,* 1(2): 13-25.

Saini, N.S. 1987. Urban and regional planning information system for India/ Other ESCAP Countries, New Delhi, India, pp. 156-189.

Sharif, M.A. 1995. *Introduction to Decision Support System and Multi-Criteria Evaluation Technique.* ITC Publication, The Netherlands, pp. 450-470.