A GIS-based Multi-criteria Analysis to Site Appropriate Locations of Hospitals in Dhaka City

N. Sharmin[1] and M. N. Neema[1*]

[1]Department of Urban and Regional Planning
Bangladesh University of Engineering and Technology
Dhaka- 1000, Bangladesh
*E-mail: mehernigar@urp.buet.ac.bd

Abstract-- **Health is one of the basic needs of human being, which is achieving significant importance globally and locally particularly in the city's perspective. Mega city Dhaka is highly confronted with extremely poor living environmental conditions and lack of basic amenities, inadequate healthcare facilities, and outreach of services. Unfortunately, there is lack of policy adaptation and implementation with regard to the spatial dimension of planning for health facilities. Moreover, the health facilities are distributed disproportionately, rather than in an equitable manner. Many poor people do not have access to the healthcare centers in the city. However, it is estimated that, the expected growth of population will put greater pressure on the already inadequate health services. Therefore, it requires examining the spatial distribution of hospitals and providing optimal locations of new hospitals. This study analyzes the existing locations of hospitals in a part of the city and find out suitable locations for providing new hospitals.. This study considers multiples criteria including distances from existing hospitals, roads, educational institutions, industries and water bodies to determine suitable places for new hospitals. To perform this study, the spatial analyst and geo-processing tools of geographic information systems (GIS) were employed. Finally, the suitable locations have been presented in a map, which implicates that the total area of suitable locations for new hospitals in the study area is 10.95 acres comprising 0.48% of the study area. This study thus provides decision makers with suitable sites for new hospital allocation to adequately cover the hospital needs in the study area.**

I. INTRODUCTION

Hospitals are one of the most important ingredients of infrastructure development. The increasing population, especially in developing countries, amplifies the demand for new hospitals. Appropriate site selection of hospitals plays a vital role in the construction, management and usefulness of hospitals. Optimal allocation of medical resources allows matching the provision of health care with the social and economic demands, improving access to the health care, reducing the time of rescue, satisfying people's medical needs as well as enhancing the quality of life [1]. Thus health planning is achieving much importance in the global as well as in the city's perspective [2]. Land-use suitability analysis is one of the most practical applications of GIS for planning [3], [4], [5], [6]. It identifies the most appropriate spatial pattern for future land uses according to specific requirements, preferences or predictors of some activity. The end product of land-use suitability analysis is a generalized map, depicting areas that are categorized as having either least, low, moderate or high suitability. The GIS-based land-use suitability analysis has been   applied in a variety of field which includes

ecological approaches for defining land suitability or habitat for animal and plant species [7], [8], geological favorability [9], land suitability for agricultural activities [10], [11], landscape planning [12], environmental impact assessment, site selection for the public facilities [13], [14], [15] etc.

GIS has also been be adapted by several researchers to combine different data and generate information required for decision making in health management. Gordon and Womersley (1997) explained the availability of relatively inexpensive, user-friendly GIS and its advantage of using map in public health and planning health service [16]. To find out the physical access of the residents to the health care center in a distant area of Andean Bolivia, GIS approach was applied by Perry and Gesler (2002) [17]. Zaman *et al.* (2005) investigated the spatial distribution of health facilities in Bangladesh using some statistical measures like Location Quotient analysis, Gini index etc [2]. By combining GIS and Location-Based Services (LBS) a system, named EmerLoc was developed by Maglogiannis and Hadjiefthymiades (2007) to settle the affairs of emergency medical incidents by [18]. Hare and Barcus (2007) used a GIS framework with geographical distributions and travel times to figure out the relevance between accessibility and health in the heart-related hospitals in Kentucky [19]. Behzadi and Alesheikh (2013) used Belief-Desire-Intention (BDI), a GIS model for estimating suitable hospital sites [20], [21].

Dhaka, the capital of Bangladesh, is one of the mega cities of the world with high density of population. In this city, the distribution of health facilities is scattered and is not located optimally. The continual growth of population will put greater pressure on the existing insufficient health services. It is therefore necessary to study first the existing locations of hospitals and find out optimal locations for additional hospitals. However, no systematic research has been conducted yet to consider GIS-based multi-criteria analysis to site suitable locations of hospitals in Dhaka city.

The aim of the study is thus to analyze existing locations of hospitals in the a part of the city and find out suitable places for providing new hospitals considering multiple criteria such as distance from existing hospitals, roads, educational institutions, industries and water bodies. To perform this study, the spatial analyst and dedicated geo-processing tools of geographic information systems (GIS) are used.

II. METHODOLOGY

After collecting data from the secondary sources, the total area of existing hospitals in different sub-districts (zones) of
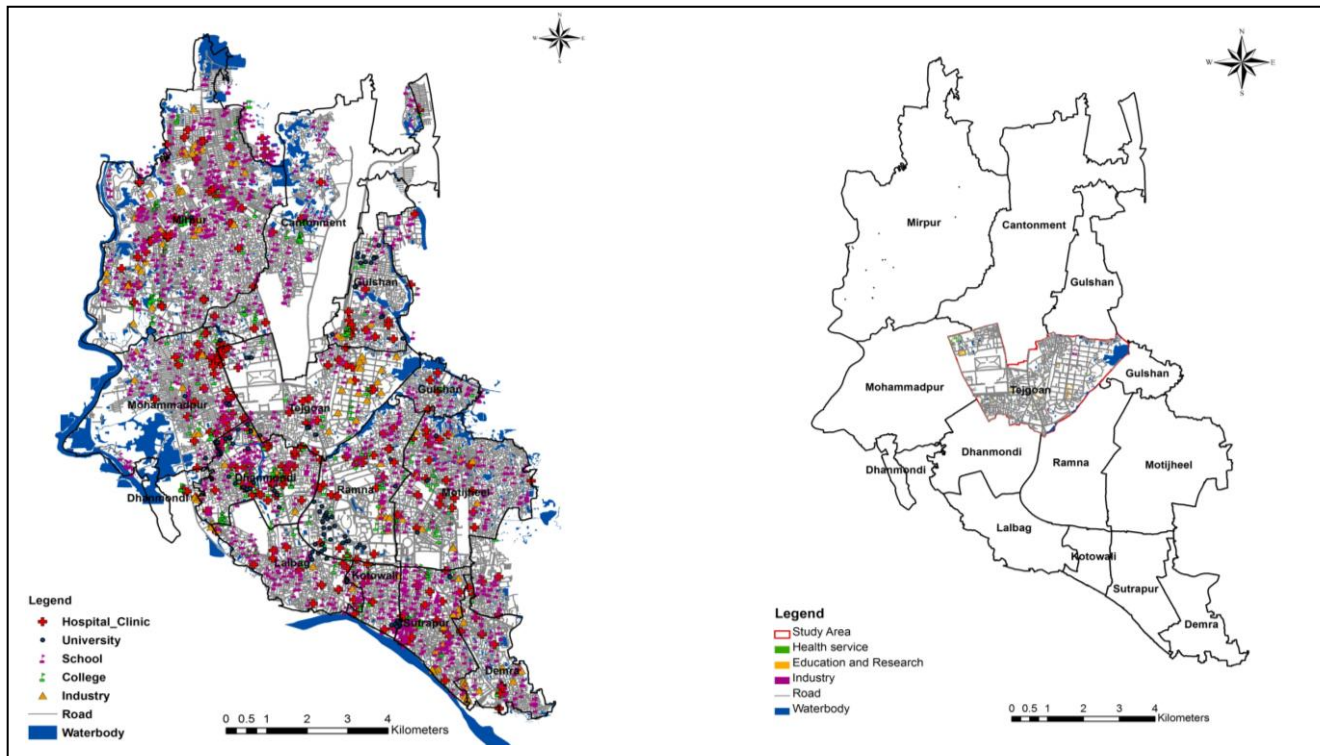
Fig. 1. Location of Existing Hospitals, Industries and Educational Institutions in Dhaka City

Dhaka City Corporation (DCC) area have been calculated. Data processing and analysis were performed using various tools of ArcGIS 9.3. Some proximity tools and overlay tools of GIS were used to discover the suitable location of hospitals in the study area. After completing the analysis some major findings have been represented. Some recommendations have also been provided based on the findings of the study.

Profile of the Study Area

Tejgaon (sub-district) is a large area (2,245 acres) situated in the centre of Dhaka. It has a population of around 302,109. Historically, this area has been serving as a centre of industrial activity in the city. Numerous plants and factories are located in this study area such as garments, food processing, metal works, pharmaceuticals, etc. Moreover, the study area has emerged as an important business district of Dhaka.

According to Private House Land Development Rule, 2004, there should be 0.04 acres of land for hospital per 1,000 populations in an urban community [22]. But in Tejgaon area only 8.4 acres of land is occupied by hospitals for a total of 302,109 population [23]; whereas according to the Private House Land Development Rule, 2004, a total of 12.08 acres of land should be provided for the health care facilities. This implies that, the considered study area has inadequate health facilities and so more hospitals should be provided for the betterment of the inhabitants of this important sub-district of Dhaka city.

Table I
Existing health services, educational institutions, industries, roads and water body in the study area [24]

Land use type	Area (in acres)	%
Hospital/ Clinic	8.4	0.37
Educational Institution	23	1.02
Industries	7.6	0.34
Road	236.3	10.53
Water body	96.4	4.29

The table I shows that, only 0.37% of the total area is occupied by hospitals or clinics, which is not adequate considering number of inhabitants of the study area. Therefore, more hospitals are required to provide for the health services of the inhabitants of this area.

Criteria for Suitable Location of Hospitals

For the aspects of location allocation, hospital site selections should take into account numerous parameters. Therefore, in this study the following criteria have been selected to analyze the suitable location of additional hospitals in the study area.

• Existing Hospitals: For the construction of new hospitals this criterion should be given importance. Keeping the distance from other existing hospitals as well as anticipating impact from each other, is not only relevance to
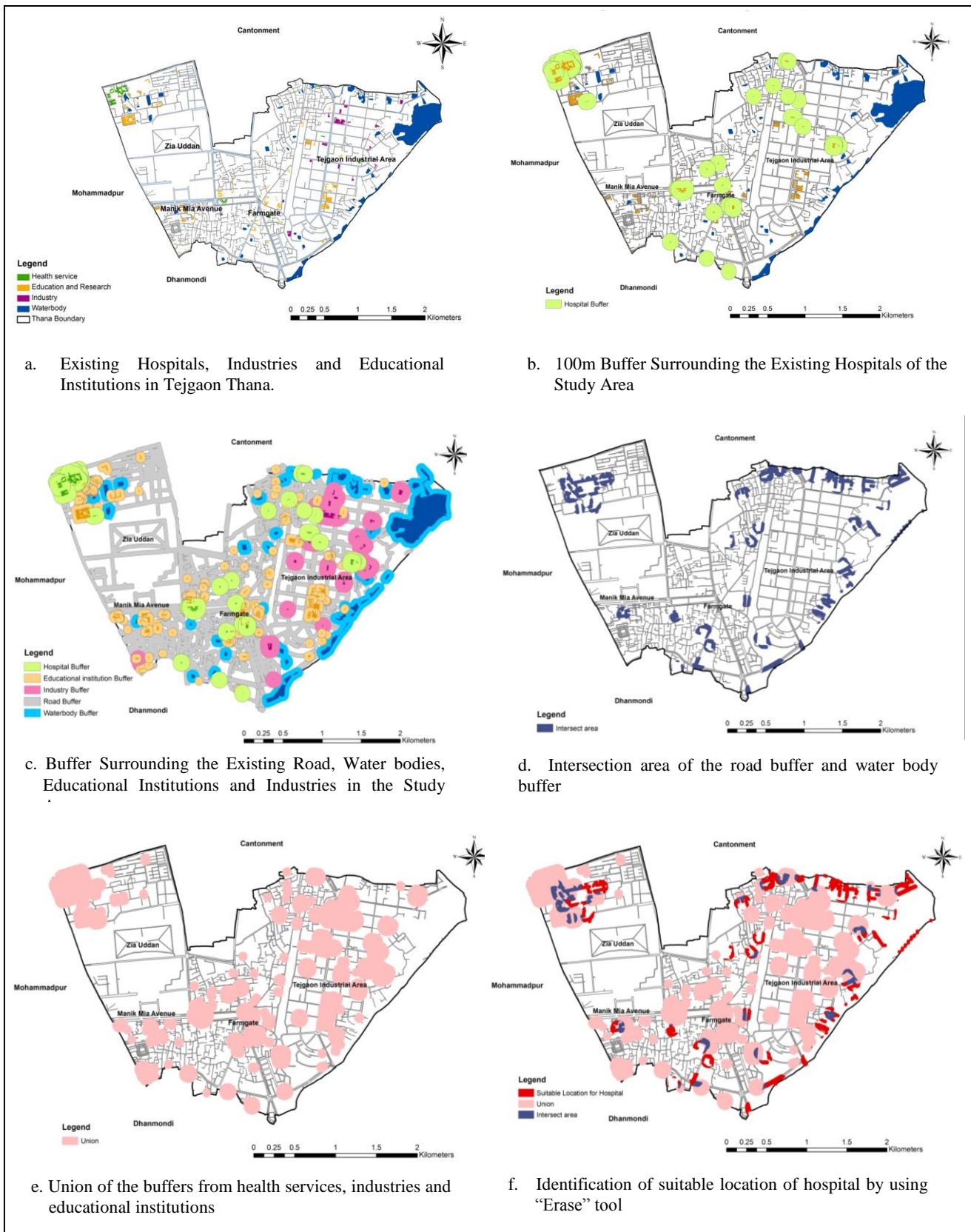
a. Existing Hospitals, Industries and Educational Institutions in Tejgaon Thana.

b. 100m Buffer Surrounding the Existing Hospitals of the Study Area

c. Buffer Surrounding the Existing Road, Water bodies, Educational Institutions and Industries in the Study Area

d. Intersection area of the road buffer and water body buffer

e. Union of the buffers from health services, industries and educational institutions

f. Identification of suitable location of hospital by using "Erase" tool

Fig. 2. Analyzing suitable location of hospitals in the study area

rational resource allocation, but also affect the competition in market economy.

•   Road: Theoretically, a hospital should be located near the roads, especially the main roads. However, the noise from motor vehicles passing by influences the patients in the hospital. Therefore, a quiet distance of 20 m is considered as a set value.

•   Industries and Educational Institutions: A new hospital should be located far away from industries so that the patient could not get affected by the polluted air and sound from the industries. Therefore, a distance of at least 100 m is decided to set in the model. Moreover, hospitals should also be at a distance from the educational institutions to avoid the noise pollution.

•   Water Bodies: In case the new hospital drains sewage to water bodies, at least 60 m distance along the water bodies should be used.

The following criteria were set for the suitable location of additional hospitals in the study:
• Within 20 m distance from the nearby roads
• Within 60 m distance from the location of water bodies
• Beyond 50 m distance from the location of educational institutions
• Beyond 100 m distance from the location of industries
• Buffering 100 m between two hospitals.

Data Processing and Analysis

The following steps were undertaken during the analysis of suitable location of hospitals in the study area using ArcGIS 9.3 software.

At first, a map is generated showing the existing location of hospitals, roads, educational institutions, industries and water bodies in the study area (Fig. 2.a). It provides a general idea about the spatial distribution of the infrastructures in the study area. Using this map, a buffer of 100 m has been made from the existing location of the hospitals and clinics (see Fig. 2.b) to obtain quantitative proximity information of the hospitals. For this, the "Buffer" tool from the ArcTool box has been used. It is evident that some hospitals are located very close to another one (within 100 m distance). So, for providing new hospitals it is justified that a hospital cannot be placed within a buffer of 100m from the nearby hospital.

Subsequently, following the same procedure buffers of 20m, 60m, 50m and 100m have been made from the locations of existing road, water bodies, educational institutions and industries respectively in the study area (Fig. 2.c). From Fig. 2.c it is observed that there are health services, educational institutions and industries which do not fulfill the criteria of suitable location of additional hospitals.

Later, the buffers from different features have been overlayed using the "Intersect" tool and "Union" tool of Arc GIS. As the suitable location of hospitals has to be within 20 m distance from the nearby roads and within 60 m from the location of water bodies, the intersection of the road buffer and water body buffer has been generated to identify the common area between them (Fig. 2.d).

Again, according to the given criteria, the suitable location has to be beyond 50 m distance from the location of educational institutions, 100 m beyond the location of industries and must have a distance of 100 m buffer between two hospitals. So, union tool has been used to identify the area where the suitable area must not be located (see Fig. 2.e). Then these two generated layers (i.e. intersection, union) have been dissolved to generalize the adjacent polygon features.

The intersection area represents the common area of the buffer from roads and water body of the study area, which can be a suitable location of hospital. On the other hand, the union area shows the area that must be eliminated while discovering the suitable location of hospitals. Therefore, the union area has been erased out from the intersection area by using the "Erase" tool to determine the suitable location of hospital in the study area (Fig. 2.f).
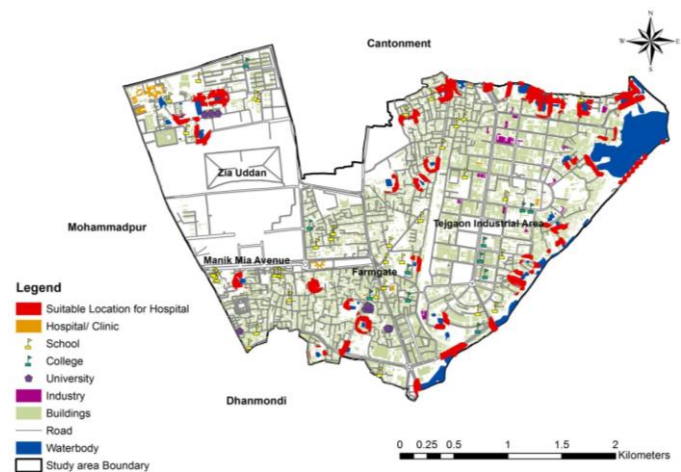

Fig. 3. Map of Suitable Location of Hospitals in Tejgaon Thana

III.   DISCUSSION

The study area is situated at the center of the Dhaka city. It has a huge concentration of residential buildings, commercial places, educational institutions, manufacturing stations and health care facilities. For a population of 302,109 [23], it occupies only 8.4 acres of land that has been used for health facilities such as, hospitals and private clinics which is not sufficient. According to Private House Land Development Rule, 2004 [22], there should be 0.04 acres of land for hospital per 1,000 populations in an urban community. Therefore, a total of 12.08 acres of land was provided for the health care facilities in the study area so that, all the inhabitants could be treated properly. Using ArcGIS, suitable location of hospitals in the study area have been analyzed. Fig. 3 shows all the suitable locations where new buildings for hospitals can be provided. The total area of suitable location of hospitals in the study area is 10.95 acres, which is about 0.48% of the total area of the study area (see table II). As a total of 12.08 acres of land should be provided for the health facilities according to Private House Land Development Rule, 2004, and the study area already has 8.4 acres of land for health services, so only 3.68 acres of land maybe utilized to build new hospitals from the suitable location in the study area. From Fig. 3, it can also be seen that except some small

clinics there are no hospitals in the study area. So, this area should get the first priority for locating a new hospital within the study area. Although there are many industries in this locality, but the map shows the suitable locations of constructing new hospitals keeping a safe distance from those industries.

Table II
Area, population and total area of suitable location for hospital in the study area.

Study area	Size (in acres)	Population (2011)	Suitable location for Hospital (in acres)
Tejgaon	2,245	302,109	10.95

IV. CONCLUSIONS

The spectrum of health situation has been changing dramatically with the global changes in health over time. The major contributors to these changes include rapid population growth, increasing urbanization and major shifts in disease patterns that prevail in a country. In Bangladesh (a densely populated country with limited resources), health care during the past 40 years did not create an equitable distribution of health services. Dhaka, the capital city, also reflects the same scenario. The primary reason is that, the allocation of health service sector never got any priority. Moreover, there is no comprehensive planning approach, which has been adopted and implemented in the city. As, there are both government and some private hospitals in this city so, not only the public but also the private sector should come forward to construct new hospitals, so that all the inhabitants of the study area can have access and get better health care facilities. This study presents the suitable location for hospital allocations in the study area thus considered from which the decision makers can obtain quantitative information about optimal locations of hospitals. It is also necessary to revise the current laws and regulations of the public health department for hospital site selection. The suggested measures and optimal locations of new hospitals can surely upgrade the present situation of health facilities of Dhaka City providing maximum services.

REFERENCES

[1] Zhou, L and Wu, J. (2012) "GIS-Based Multi-Criteria Analysis for Hospital Selection in Haidian District of Beijing", Department of Industrial Development, IT and Land Management, China.

[2] Zaman, S., Islam, T. and Karim. S. (2005) "Spatial Distribution of Public Health Facilities in Bangladesh: A Regional Analysis", Department of Urban and Regional Planning, BUET, Dhaka.

[3] Brail, R.K. and Klosterman, R.E. (2001). Planning Support Systems, ESRI Press, Redlands, CA.

[4] Collins, M.G., Steiner, F.R., Rushman, M.J. (2001) "Land-use suitability analysis in the United States: historical development and promising technological achievements". *Environmental Management*, Vol. **28**, No. 5, pp. 611–621.

[5] Hopkins, L. (1977) "Methods for generating land suitability maps: A comparative evaluation", *Journal for American Institute of Planners*, Vol. **34**, No. 1, pp. 19–29.

[6] McHarg, I.L., 1969. Design With Nature, Wiley, New York.

[7] Pereira, J.M.C., Duckstein, L. (1993) "A multiple criteria decision-making approach to GIS-based land suitability evaluation". *International Journal of Geographical Information Systems*, Vol. **7**, No. 5, pp. 407–424.

[8] Store, R., and Kangas, J. (2001) "Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modeling". *Landscape and Urban Planning,* Vol. **55,** No. 2, pp. 79–93.

[9] Bonham-Carter, G.F. (1994). Geographic Information Systems for Geoscientists: Modeling with GIS, Pergamon Press, New York.

[10] Cambell, J.C., Radke, J., Gless, J.T., Whirtshafter, R.M. (1992) "An application of linear programming and geographic information systems: Cropland allocation in antigue". *Environment and Planning A,* Vol. **24**, pp. 535–549.

[11] Kalogirou, S. (2002) "Expert systems and GIS: An application of land suitability evaluation", *Computers, Environment and Urban Systems,* Vol. **26**, No. 2–3, pp. 89–112.

[12] Miller, W., Collins, W.M.G., Steiner, F.R., Cook, E. (1998) "An approach for greenway suitability analysis", *Landscape and Urban Planning,* Vol. **42**, No. 2–4, pp. 91–105.

[13] Eastman, J.R., Kyem, P.A.K., Toledano, J., Jin, W. (1993). GIS and Decision Making, UNITAR, Geneva.

[14] Church, R.L. (2002) "Geographical Information Systems and Location Science". *Computers and Operations Research*, Vol. **29**, No. 6, pp. 541–562.

[15] Janssen, R., Rietveld, P. (1990) *Multicriteria analysis and geographical information systems: an application to agricultural land use in the Netherlands*. In: Scholten, H.J., Stillwell, J.C.H. (Eds.), Geographical Information Systems for Urban and Regional Planning, Kluwer Academic Publishers, Dordrecht.

[16] Gordon, A. and Womersley, J. (1997) "The Use of Mapping in Public Health and Planning Health Services", *Journal of Public Health Medicine,* Vol. **19**, pp. 139–147.

[17] Perry, B., Gesler, W. (2002) "Physical access to primary health care in Andean Bolivia". *Social Science & Medicine,* Vol. **50**, pp. 1177–1188.

[18] Maglogiannis, I., Hadjiefthymiades, S., (2007) "EmerLoc: Location-based Services for Emergency Medical incidents". *International Journal of Medical Informatics,* Vol. **76**, pp. 747–759.

[19] Hare, T.S., Barcus, H.R. (2007) "Geographical Accessibility and Kentucky's Heart Related Hospital Services". *Applied Geography,* Vol. **27**, pp. 181–205.

[20] Behzadi, S. and Alesheikh, A.A. (2013), "Hospital Site Selection using a BDI Agent Model", *International Journal of Geography and Geology*. Vol. **2.** pp. 36-51.

[21] Vahidnia, M.H., Alesheikh, A. and Alimohammadi, A. (2009). "Hospital site selection using fuzzy AHP and its derivatives". *Journal of environmental management*, Vol. **90** No. 10, pp. 3048-3056.

[22] Bangladesh Gazatte (2004) "Private House Land Development Rule", March 1.

[23] BBS (2011), Bangladesh Population and Housing Census 2011, Community Report, Dhaka: Bangladesh Bureau of Statistics.(Forthcominghttp://www.bbs.gov.bd/WebTestApplicatio n/userfiles/Image/Census2011/Dhaka/Dhaka/Dhaka_C01.pdf , accessed on January 17, 2013.

[24] DAP (2010) "Dhaka Metropolitan Development Plan, Detailed Area Plan". RAJUK, Dhaka.