The Design of Geographic Information System Education Administration Tools for the Saudi Ministry of Education (MOE) in Saudi Arabia

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Abstract:

A Geographic Information System (GIS) is a suitable tool for decision making. GIS can provide the educational planner with processed spatial data that can be analysed and displayed as digital maps. Modern technology has been adopted recently in Saudi Arab. The implementation of GIS in the education system in Saudi Arabia will provide the tools to enable the educational planner in the Ministry of Education (MOE). Hence the integration of GIS and suitable Multi-Criteria Evaluation (MCE) techniques will facilitate the school site selection process and strengthen the use of GIS as a tool for decision making. Therefore, the aim of this study is to introduce integrated models of GIS and multi-criteria evaluation techniques (MCE) for school site selection and to pave the way for implementation of GIS technology in (MOE). As result of this study, authors provide a framework for possible GIS applications in administration and planning aspects for (MOE) in Saudi Arabia. The expected results will contribute to suitable school distribution and as a tool for school opening or

closure plans and minimizing the cost of future plans. Finally, the site selection and catchments models have been developed for this study can be used in similar organizations selection such as, colleges, mosques, restaurants, sport club, bank, super market, hospitals and ambulance services.

Key words:

Geographic Information Systems (GIS), Multi-Criteria Evaluation (MCE). Ministry of education (MOE), Saudi Arabia, School site selection. Criteria

INTRODUCTION:

The original use of GIS was in map production. However, GIS now use as a tool for policy analysis and for improving the quality of planning and decision making process (Clarke and Langley 1996; Nijkamp and Scholten, 1993, Nath et al, 2000). For educational planning and administration, planners need to know which site would be most suitable for institutional facilities. The power of GIS is in its ability to deal with different sets of data for processing, analysing, storing and visualizations. Moreover, GIS is capable of answering such question as: Where is the best school site? What are the actual locations of existing schools? Where are the plots assigned for educational buildings? Furthermore, GIS offer the potential of a dynamic core for school planning. School site selection is of major importance for educational planners. In Saudi Arabia GIS is now being employed at MOE and it is expected to be used by other similar agencies. More specifically, MOE has started to review their educational

systems, particularly the management and administration systems. Obviously, these changes encounter some difficulties. The anticipated problems facing the planners and decision makers in MOE are spatial or geographical problems; lack of information about MOE properties, determining optimum school locations, school catchments areas, redistricting schools, demographic information and population distribution, and student addresses. Some of the previous problems have been solved using traditional methods, but some still exist. For example, the spatial planning problems faced by the decision makers in MOE cannot be addressed by the traditional methods alone, particularly at a time when decision-making tools are available.

The study objective is to provide possible solutions to some of these problems using a PC-based GIS previously applied successfully in many similar situations for school allocation problems. In order to achieve this aim, the researches will try to fulfil the following objectives:

1. Evaluate and improve some criteria for school locations, based on international and MOE standards.
2. Evaluation of some Multiple-Criteria Evaluation (MCE) techniques and develop optimum available school location models in the study area, using different GIS packages.

RELATED WORK:

(GIS) are becoming an increasingly integral component of natural resource management activities, socio-economic and environmental planning. Nath et al (2000)

believe that the most significant development is an increasing trend towards the use of GIS as a component of a larger decision support system in addition to an increasingly important role in landscape visualization. Furthermore, the decision makers can perform interactive communication by the use of a local area network. Also, deployment of Internet enabled GIS tools allow decision makers to have instant access to spatial data. The successful uses of GIS in planning justify the trend towards implementing and developing different GIS applications in local government for urban and regional planning, community planning, site selection problems for business markets, natural resource management, and environmental planning, with increased support from GIS software vendors. Looking to the benefits to state and local government, there are valuable functions of GIS in urban and regional planning. For example, GIS technology enables the planners to create and test alternative development scenarios, investigate and plan the infrastructures of any area or country, locate the public utilities such as electricity, water, sewage systems, communications, transportation and roads network and residential areas. Furthermore, it can enhance the organization and performance of local or regional government.

GIS provides the tools that save time and money as well as enabling the of choice of suitable store locations based on the search for potential sites and the analysis of the regional and community needs, the type of consumers, income rate, or preferences. All these data can form customer's profiles and a market database that can be used to explore the market and the competition locations. Furthermore, GIS has the ability to

simultaneously search for and rate potential sites. Some companies are even using GIS to target potential employees. In addition, the technology enables retailers to evaluate how opening multiple locations in a geographic region will impact the bottom line. GIS software is an easy-to-use graphical user interface (GUI) which includes tools, models and functions that enable the user to enter, store, analyse, query, manipulate, display and print geographical information. The rapid increase in the use of technologies has created competition among computer technology manufacturers to produce highly adequate systems software. GIS software ranges from basic software appropriate for displaying maps to very large programs for more sophisticated operations. It has become possible to use and develop many GIS applications using PC-based GIS systems. GIS has the potential to improve data integration and spatial analysis in term of time and accuracy, provide general data management, documentation analytical capability. Furthermore, the GIS enable users to change the search criteria in what is known as "what if?"

Buttenfield (1994) argues that GIS facilitates the dialogue between the student and him/herself in what is known as virtual communication. Likewise, Goodchild and Kemp (1990) introduced three reasons for applying GIS in the school curriculum. Also, GIS enables teachers and students to explore and analyse information in new ways (Barstow et al., 1994).There were many contributions advocating the use of GIS from primary levels to higher education levels to assist students to visualize their projects, maps and spatial applications (Barstow, et al. 1994 and, Bednarz, 2004).

In fact, many education authorities in most countries have realized the potential role of GIS in planning and administration. For example, in USA students use GIS advanced applications and satellites. (Baker, 2002 and 2005). The opportunity for GIS diffusion in Canada is similar to that in the USA. Furthermore, in UK there are some examples of GIS applications and activities carried out by students in UK classrooms. Several schools can deal with its own local area data including digital maps, satellite images, and historic data. (ESRI 2003).

One problem that might face educational planners and decision makers concerning school site selection is the choice of the best locations from a large number of choices by considering a large number of attributes. Thus, Multi-Criteria Analysis (MCA) methods assist them in making the right decision when selecting the optimal solutions from among the multi-criteria and conflicting objectives. Many techniques are adopted to evaluate alternative choices, for example, different planned sites. (MCE) methods are frequently used in the field of planning, and policymaking. (MCA) provides the tools for decision makers because of its ability to deal with many criteria (Janckowski and Richard, 1994). On the other hand, (MCA) consists of Attribute Decision Making (MADM) or Multiple Objective Decision Making (MODM) (Jankowski, 1995, Nijkamp and Scholten, 1993 and, Carver, 1991). Criterion is a generic term that includes both the attributes and objectives (Malczewski, 1999). Hence, (MCE) problem includes both the attributes and objectives. In this research, school site optimization is the only objective with multi-attributes that the research

handles. Therefore, the term MCE is used here to refer to the problem of one objective and many attributes. MCE is not a stand-alone software package but it is considered as a mathematical model ("in–built" in some software) needing a set of factors or elements of a proper framework model, data, well-trained users and analysts. A MCE approach is carried out through a process (Larribi et al., 1996) MCE methods are many and varied. One of the most commonly used methods for evaluating MCE having continuous criteria is Weight Linear Combination (WLC) and Concordance & Dis-concordance Technique (Carver, 1991). (WLC) can be implemented in both vector and raster GIS. The integration of MCE and GIS is very important. For example, using this combination, Spatial Design Support System (SDSS) models are developed. The final user of this technique (in our case the education planner) will be able to make the correct choice of school sites.

Since substantial geographic data and geographic based applications and models are now available. Geographic analysis and applications require both spatial and attribute data to be put together. This researcher believes that it is now time to use location-based models which can be tackled very easily using GIS environment rather than the conventional method. Densham (1991) indicates that the extended network model is the best model for representing spatial relationships, rather than the usual relational data model, which has been used in the DBMS. Using raster GIS to explore site suitability needs specific criteria and a wide range of spatial data sources. Raster GIS is recommended for performing site suitability analysis incorporating multi-criteria

models. It can be seen from the review of GIS in education that the most common use of GIS in education is for school site selection and redistricting of school catchments areas. The review reveals that the development of GIS spatial analysis models enables the user to perform analysis such as overlay, buffer, network and many more (ESRI, 2003, 2003, Brent et al., 2003, Svatos, 2001, Beck 2005, Kitsio et al., 2002, and Shalaby et al,1998).However,The literature on the use of GIS in education demonstrates clearly the efforts of researchers and GIS specialists since early nineties unite now Green, 1993, Barstow, et al. 1994, Barron 1995, pizzolato et al, 2004 and Parky 2005).

GIS in Saudi Arabia

The modern technology of Geographic Information Systems has been adopted recently in Saudi Arabia as shown by attempts in the private sector to produce tourist maps for some areas by the Al-Farsi mapping agency. Also, Al-Daleel Company adopted GIS for two projects in Riyadh and Jeddah city. The project presents the use of digital maps, information systems, elevation data and GIS technology for creating a "visual tourist guide" for visitors to these two cities (Al-Daleel, 2003 a, b).

In Saudi Arabia, as in any other developing country, the incomplete infrastructure and the absence of modern maps are the two most important factors that have delayed the use of modern technology. These imply the unavailability of large-scale maps for the city of Riyadh, with the absence of street names, house numbering, and post coding of areas, for instance. In addition, there are no clear plans for using GIS and integrating

it into education and government or private business. The need for the implementation of GIS technology in Saudi Arabia has become pressing, from the observation of other countries that have used GIS in their business. The great benefit of implementing GIS in the government civilian sectors, such as the Ministry of Education (MOE), the General Presidency of Girl Education (GPGE), Ministry of Health (MOH), and the Civil Protection Department (CPD) and in many other similar services, ministries and departments is clear. The infrastructure of most GIS components is now present to some extent; for example, the availability of data, manpower, hardware and software and applications will increase the spread of use of GIS. The rapid improvement in computer technology makes it easier and cheaper, compared to three or four decades ago. These days perhaps the most important factor in a country like Saudi Arabia is the availability of data.

Research methodology and procedures:

The aim of this study was the implementation of (GIS) in education administration and planning. The role of GIS for suitable school sites was studied and a wide range of literature (1990 to 2005) was covered. Some available programs and applications have been examined and compared to investigate the possibility of using them in this research. Authors gained experience of different GIS packages, each having different functions and purposes. ArcGIS, ArcView, IDRISI, GeoChoice and Expert Choice packages served as assistance tools for decision making. The researchers negotiated

with MOE to select a study area that would be ideal for this application. MOE provided data such as student and school records, MOE properties and vacant land (lot) already assigned for new schools. In addition, both GDMS (General Directorate of Military Survey) and MOMRA provided spatial data for the study area in digital form at different scales.

Indeed, 16 factors were selected as the most possible to represent school sites criteria. They were chosen to ensure accessibility, safety, availability, regular distribution, reasonable location size and shape. These criteria were of two types, constraints and factors. Constraints work as a mask map to exclude undesired areas while factors were converted into common scale maps via standardization processes so that they can be evaluated. Therefore, in order to measure selected criteria preferences and priorities, a questionnaire survey was conducted with participants from three categories. Participants from MOE ensured that the criteria would be evaluated from an educational planning point of view. A second category was the people from the GIS centre in GDMS, as they would reflect the importance and preference of the selected criteria from a technical point of view. The final sample was composed of students' parents (SP). The questionnaire consisted of two parts in two different designs. First part was in matrix form, such that the pairwise comparison method could be employed using Expert Choice and IDRISI packages. The second part was similar to the evaluation table in ModelBuilder™ in the ArcView package. In spite of the sample being very small, it was difficult to get back all distributed questionnaire.

Consistency test, central tendency measurements and mean value of each group have been carried. The author accomplished criteria evaluation as well and results were compared to the participant's evaluations (See table 1).

PROPOSED APPROACH:

The suggested approach consists of three parts: first, the identification of the feasible alternative sites; secondly, aggregation of criteria relative to the scope of site selection; and finally developing the appropriate model for aggregation of the GIS and suitable techniques of MCE (Figure, 1). The proposed approach would be the guide for the research to produce the required models for the school site selection and catchments models.

MCE MODELS AND SUITABILTY MAPS

MCE consists of Attribute Decision-Making (MADM) or Multiple Objective Decision-Making (MODM) Hence; a multi-criteria (MCE) problem includes both the attributes and objectives. This research deals with a spatial problem of multi-criteria and one objective, which is finding the best school locations. Thus, the choice of the most appropriate MCE was important, as there are factors that need consideration such as decision situation and method assumptions. Therefore, it seemed that the most suitable direct method for processing MCE that has continuous criteria was the weighted linear combination (WLC) model. The model provides the trade-off among

employed criteria importance and priority and requires the criteria to be weighted properly and standardized to a common scale, for example, ratio scale. Hence, the pairwise comparison approach (PWC) derived in the mathematical model of analytical hierarchy process was used to measure the relative importance of criteria. The combination of (MCE) and (GIS) facilitated the process of site suitability evaluation and analysis. The idea behind this combination is based on the capability of GIS to provide decision alternatives, with some analysis possibility in some GIS systems, and MCE offering the mathematical model. Different site suitability projects were presented in the literature that utilized built-in MCE in GIS packages or developed their own MCE routine compatible with the GIS software. Among many GIS software that have built-in MCE techniques like the WLC method, two of them were employed in this study, namely, ArcView and IDRISI.

The two systems have produced to some extent different suitability maps. The decision options produced by the MCE routine in ArcView and IDRISI were compared. The criteria weight method could be the basic reason for the dissimilarity. While the criterion evaluation weights obtained from the survey analysis were direct ratings in ArcView ModelBuilder (MB), the process was different in IDRISI. The criteria weights were taken into Expert Choice system (EC) to create the analytical hierarchy model and then the pairwise comparison weights. AHP criteria structure in EC generated two kinds of weights, global and local. Another reason that led to dissimilar suitability maps is the suitability scale. The IDRISI system generates maps

in a continuous scale ranging from zero to 255 byte whereas ArcView creates a discrete suitability map based on a customized user scale like one to three categories, high, medium and low suitability. A visual comparison and statistical tests performed on all maps visually explored the variation and measured the differences. Both local and global weights displayed visible differences on IDRISI maps. Using local weights (See figure, 2), more suitable areas were shown in the author, GIS, SP, and MOE maps respectively, whereas MOE maps using global weights present more areas that are suitable. It can also be noticed visually from the resulting maps the effect of the higher weight of the highway criterion. The reason was that the highways factor represents accessibility and hazardous areas at the same time. On the other hand, ArcView maps produced dissimilar results as well and suitable areas were apparent in all maps (Figure, 2). The obvious visual difference to ArcView maps was the absence of highly suitable zones. Comparisons, the maps produced by IDRISI were converted into ArcView to measure the amount of suitable land obtained by both systems.

Coincidence summary via MDCHOICE module in IDRISI also assessed the similarity between maps via map overlay. Likewise, the CROSSTAB module provided summary information for each map. In addition, principal component analysis (PCA), one of the most powerful multivariate tools, is used to investigate the variability between groups of variables. Three components studied, analysed and correlation were explored between components.

Selecting School locations

The authors have utilized the possibility of customizing the graphical user interface (GUI) provided by ArcView software to design and create a tool that facilitates operating the developed models. The graphical user interface (GUI) tool facilitated the use of school site analysis models for several reasons. With the aim selecting new school sites, the Authors and MOE maps were chosen as examples for comparison purposes. Furthermore, to ensure the appropriateness of selected sites, three additional criteria were added to the final choice process, namely, location shape, area and student numbers. The latter will be used to analyse the catchment model. The other two conditions are a minimum site area of 2000 sqm and shape dimension (length/width) of not less than 0.230. Locations not fulfilling the two conditions simultaneously will be excluded. A comparison test showed the variation in suitable location numbers and the probable land parcels achieved from various suitability maps. Suitability maps created in IDRISI produce more suitable school locations. The resulting locations have been employed with the old school locations in the study area to generate the school catchments.

Catchment models:

Three catchment models, circular, hexagonal and network, are developed for comparison and in order to choose the most suitable catchment model for the study. In addition, catchment analysis employed different options provided by the catchment tool, such as the distance-based constraint, distance-capacity based constraint, school

capacity-based constraint, or unconstrained catchment. The three models tested and compared against these options. All models demonstrated large variation in suitability. Moreover, building counts in the study area were used to calculate student numbers, to compensate for the absence of student or population census data. All catchment models demonstrated suitability variation and representations. According to the available old and new school locations, the circular and hexagonal models based on capacity-distance constraint provide more flexibility and would be preferred over the other catchments based on capacity or distance. Although there is consistency and regularity in the hexagonal catchment shape, it was of less extent than the circular shapes. On the other hand, the capacity based network catchment provided more suitable catchments compared to the capacity-distance combination and distance based only.

Generally, the circular and hexagonal models retain the problem of catchment overlaps compared to network models but their advantage resides in the assurance of walking distance condition for the school pupils. By providing accurate road network data, network shape would more preferred for Saudi schools if the walking distance is not required. It seems that the process of merging some schools, moving rented ones and utilizing the new locations suggested by this study will provide the best school locations and catchments.

FINAL DISCUSSION:

This research studied the best locations for Saudi Arabian schools according to various criteria. Different points of views were considered ranging from stakeholders to students' parents. The reason for involving these views was to assist and evaluate the selected criteria particularly in the case of enlarging or changing the study area to another city and the possibility of providing more data when implementing more criteria. This study deals with spatial problem of multicriteria, which necessitates the use of the general multicriteria evaluation method (MCE). Hence, the researchers proposed using the weighted linear combination technique (WLC) as it provides the trade-off among employed criteria. Based on the result of school site models developed in this study it seems that the models created in IDRISI software are more appropriate to be used in the school site selection process since the WLC technique and pairwise comparison method for criteria are readily available and very effective. The other aspect for this study was to define the appropriate method to determine school catchment areas. Among the different models developed for this purpose, such as circular, hexagonal and network, the capacity distance combination model was best, whether using a circular or network catchment to provide a reasonable service area for each school.

The schools site and catchment models in this research were developed in an area that has a regular shape. Most of urban areas in Saudi Arabia are characterized by regularity of shape and considerable similarity. The present study area is too small for exploring all possible problems that might be encountered when establishing new schools. However, this is not the case in all parts of Saudi Arabia. In rural areas or in the southern region of the country where the topography of the land is different, the models need some modification so that they can be applied effectively. For example, more information needs to be collected about site levelling, land topography, orientation and soil type. Thus, more criteria can be developed to enhance the site selection models so they may be made to work efficiently in both urban and rural area. For catchment models, students walking distance would be inapplicable in rural areas since the population (students) come from various and long distances. Hence, the school service area would be studied differently, according to residential zones, for example. In general, the site selection and catchments models developed in this study can be used in Saudi Arabia and similar countries for different applications. In the Ministry of Health, the principles developed here could be used to find the best locations for hospitals; primary care unites locations and ambulance services. Also, outside the Ministry of Health, the software would be beneficial in locating services centres such as petrol stations, shopping centres, fast food restaurants and mosques.

CONCULSSON

The anticipated results of this study open the doors to implementing GIS technology into MOE. Therefore; this research provides a framework for possible GIS

applications in administration and planning aspects for the Ministry of Education in Saudi Arabia. The research contains a large number of concepts and basic requirements for designing GIS tools to support the decision makers and planners in MOE in selecting the best school sites and defining the boundaries of schools catchment areas. As result researchers have proposed that the designed tools would work appropriately in countries, which have never experienced the potential of GIS in education and with limited resources and data. Finally, the design of GIS education administration tools for the Saudi (MOE) would be the basic GIS application that the MOE can start with for implementing GIS technology in education. There are more promising and exciting GIS applications that can be used beyond the education administration and planning purposes.

References:

1. AL-DALEEL, (2003A), Riyadh City Explorer, CD. Al-Daleel for Information Systems, 1,
2. AL-DALEEL, (2003B), Jeddah City Explorer, CD. Al-Daleel for Information Systems, 1,
3. BAKER, T.R., (2002), The effects of Geographical Information Systems (GIS) Technologies on students' Attitudes, self-efficacy, and Achievement in Middle School Science Classrooms, Department of Teaching and the Faculty of the Graduate School, The University of Kansas, USA, Dissertation.

4. BAKER, T.R., (2005), The History and Application of GIS in Education: *Available on line:* http://spatialnews.geocomm.com/editors/tbaker.html, > [Access on: 01.November, 2005].
5. BARRON, D.D.,(1995), Bringing the world and information together: Geographic Information System for education. *School Library Media Activities Monthly*, **11**, (5), 49:50.
6. BARSTOW, D., et al., (1994). An introduction to GIS in education. First national conference on the educational application of Geographic Information Systems (EDGIS).
7. BECK, S., (2005).The development of a prototype municipal government information system [online].Available at :< http://danenet.wicip.org/gisedu.htm. [Access on: 20.05.2005].
8. BEDNARZ, S.W.,(2004), Geographic Information Systems: A tool to support geography and environmental education. *GeoJournal*, **6**, (2), 191:199.
9. BRENT, H., et al., (2003), EduPlan: Decision support tool for education planning, program. R+GIS Applications Group, University of Waterloo, Ontario. Canada, Ver: 2.0.6,
10. BUTTENFIELD, B., (1994). GIS in education: A vision for the future. First national conference on the educational application of Geographic Information Systems (EDGIS), Washington D.C. Cambridge, Massachusetts, sponsored by national Science Foundation and National Geographic Society, TERC Communications.
11. CARVER, S.J.,(1991), Integrating multi-criteria evaluation with geographical information systems. *International Journal of Geographical Information Systems*, **5**, (3), 321:339.
12. CLARKE, G.P. and LANGLEY, R.,(1996), A review of the potential of GIS and Spatial modeling for planning in the new education market. *Environment and Planning c: Government and Policy*, **14**, (3), 301:323.

13. DENSHAM, P.J. (1991), "Spatial decision support systems" in Geographic Information Systems: principles and applications. In *Geographic Information Systems: Principles and Applications*, Eds. Maguire et al. Longman, Harlow, Essex. UK
14. ESRI, (2003). The Community Atlas [online]. Available online at :< www.esri.com/industries/k-12/atlas/>. [Access on: 23.7.2003].
15. GOODCHILD, M. and KEMP, K., (1990). *The NCGIA Core Curriculum in GIS*. National Center fire Geographic Information Analysis, University of California-Santa Barbara CA.
16. GREEN, D.R. (1993), GIS education and training: Developing educational progression and continuity for the future. In *The Yearbook of the Association for Geographic Information*,eds. Cadoux-Hudson, J. and Heywood, I. Taylor & Francis. London.
17. JANKOWSKI, P. and RICHARD, L.,(1994), Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for route selection. *Environment and Planning B*, **21**, 323-340.
18. JANKOWSKI, P.,(1995), Integrating GIS and Multiple Criteria Decision Making Methods. *International Journal of Geographical Information Systems*, **9**, (3), 251-273.
19. KITSIO, D., et al., (2002), Multi-dimensional evaluation and ranking of coastal area using GIS and Multiple criteria choice methods. *The science of the total Environment*, **284**, 1-17.
20. LAARIBI, A., et al.,(1996), A spatial decision Aid: A multicriterion Evaluation Approach. *Computer Environmental and Urban Systems*, **20**, (6), 351-366.
21. MALCZEWSKI, J.,(1999), GIS and Multicriteria decision analysis. 1. John Wiley & Sons, Inc, Canada.

22. NATH, S.S., et al., (2000), Applications of geographical information systems (GIS) for spatial decision support in aquaculture. *Aquaculture Engineering*, **23**, 233:278.
23. NIJKAMP, P. and SCHOLTEN, H.J.,(1993), Spatial information systems: design. modelling and use in planning. *International Journal of Geographical Information Systems*, **7**, (1), 85-96.
24. PARKY, (2005).A Bibliography on GIS application on education [online]. Available at: <http://oregonstate.edu/~parky/gisunanotated. html. > [Access on: 01.November, 2005].
25. PIZZOLATO, N.D., et al.,(2004), School location methodology in urban areas of developing countries. *International Trans Operational Research*, **11**, (6), 667:681.
26. SHALABY, T., et al., (1998). An 'Intelligent map' for monitoring recycling centres in Nottingham using GIS. Twelfth Annual Symposium on Geographic Information Systems, Toronto, 271-273.
27. SVATOS, V., (2001). Locating Potential School sites. 21 Annual ESRI users conference