A GIS-Assisted Optimal Urban Route Selection Based On Multi Criteria Approach

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ABSTRACT

Route planning analysis in Geographical Information System (GIS) provides strong decision support for users in searching optimal route, finding the optimal path is an important advanced analysis function in GIS. This paper presents the problem of selecting route to connect two locations in Baghdad city; Alkadomiyah and Algria'at. Four alternatives were investigated using a multi criteria approach and spatial decision support system, (SDSS) that will assist a decision-maker, to select the optimal route for a new road path. In ARCGIS 9.2, spatial analysis has been used to carry out the search strategy. In general, the goal of this study is to develop a (GIS) - based model to determine suitable route. Therefore, the required data for the proposed model building were identified by using, land use, transportation maps, aerial photographs and demographic features then reviewed for model development requirements. Four factors were considered; Geotechnical, Geometrical, social and economical factors for multi-criteria evaluation to select the best route alternative. ARC GIS 9.2 software was used for the analysis and model building requirements. In actualizing the aim, satellite images of the study area was provided while the land-use map was obtained from Design Office-Amanat Baghdad. The land-use over the study area was classified into eight different classes. A Digital Elevated Model (DEM) over the study area was downloaded from the Global Mapper Software, used to derive the slope map over the area of study and the Analytic Hierarchy Process (AHP) was used in weighting the criterions. Finally, the case study demonstrated that GIS based on multi-criteria approach is recognized to be used as a tool for the optimum route selection by considering the factors affecting on the decision-maker route selection. Furthermore, saving of money, time and effort.

الخلاصة

تحليل تخطيط الطريق باستخدام نظم المعلوماتِ الجغرافية (GIS) يوفرقراردعمَ قوي للمستخدمين في البحث عن الطريق الأمثل، ويعتبر إيجاد الطريقَ المثاليَ في نظم المعلوماتِ الجغرافية هي وظيفةُ تحليل متقدّمةِ. هذا البحث يعرض مشكلة اختيار طريق لربط موقعين في مدينةِ بغداد؛ الكاظمية والكريعات، تم دراسة أربعة بدائل باستعمال التقييم المتعدد المعايير ونظام دعم قرار مكاني (SDSS) ،الذي سَيُساعدُ في صنع القرار لاختيار الطريق الأمثل في مسار الطريق الجديدِ. وبمساعدة (ARC GIS 9.2) ، تم استعمال التحليل المكاني للقيَام بإستراتيجيةِ البحث. في العموم، إن هدف هذه الدراسةِ هو تُطويّرَ نموذج في نظم المعلوماتِ الجغرافية (GIS) لتحديد الطريق الأمثل. ولذلك، فان البيانات المطلوبة لبناء النموذج المُقتَرَح سيكون باستخدام خرائط استعمال الأرض، خرائط النقل، صور جويّة والخصائص السكّانية تبعا لمتطلباتِ تطوير النموذج. وتم اعتبار أربعة عوامل؛ (العوامل الاقتصادية والاجتماعية والهندسية وخصائص التربة) لتقييم المتعدّدِ المعاييرَ لاختيار أفضل طريق.تم استعمال برنامج (GIS ٩,٢) لأجل التحليل وبناء النموذج. ومن اجل تَحقيق هذا الهدفِ، تم الحصول على صور الأقمار الصناعية لمنطقةِ الدراسة بينما تم الحصول على خريطة استعمال الأرضَ من دائرة التصاميم في امانة

بغداد. وتم تصنيف خريطة استعمال الأرضَ لمنطقةِ الدراسةِ إلى ثمانية أصنافِ مختلفةِ و تحميل ملف الارتفاعات الرقمية (DEM) لمنطقةِ الدراسة مِنْ برنامج (Global Mapper) وأُستَعملُ ملف الارتفاعات الرقمية لاستنباط خريطةِ الانحدار لمنطقةِ الدراسةِ وتم استعمال عملية التدرج التحليلي (AHP) في تقييم المحددات. أخيراً، فان الدراسةُ الحالية تبين بأنَّه نظمَ المعلوماتِ الجغرافية المستند على نظام المتعدد المعايير يمكن أن تستَعملَ كأداة لاختيار الطريق الأفضل باعتبار العوامل المؤثرة في صنع القرار لاختيار الطريق بالإضافة إلى توفير المال، الوقت والجهد.

KEYWORD: Route Selection, Geographical Information System (GIS), AHP, Land use, DEM, Multi Criteria, Spatial Analysis.

INTRODUCTION

Route selection is a critical first step in the process of design and construction and has a potential significantly impacting the construction and environmental of the area. Effective route selection process is very important for minimizing economical cost. In planning a suitable road network, planners put into consideration factors like gradients or slope of the area, available land-use and soil type, community or national landmarks and governmental interest. These different considerations and interest make the planning process complex and as such there might be confusion of interest in the decision making (Isah O. A., 2008). The use of GIS and Multi-criteria analysis has helped planners to achieve desired and more accurate results and as such reducing the complex nature in the planning process allowing different stakeholders to reach a general conclusion, (Athina S.,et al,). Deciding the location of a highway is important during the design period. It affects not only construction costs and transportation effectiveness but also its role in road network. (Zhang, al, 1997). Route planners request input about preferred route characteristics in order to provide the user with the optimal route (Hartwig H. H., 2006). Further, the relative importance of route selection criteria for a user often depends on the route alternatives actually found between origin and destination. It can be said that integrating the decision process of a new highway location into GIS has a bright future (Chen et al, 2001). Spatial Decision Support Systems are widely used in site selection studies to locate the most suitable areas which satisfy the exclusion and preference rules that have been set by the decision makers (Massam, 1988) . Determining the best route through an area is one of the oldest spatial problems. Furthermore spatial decision systems ought to include methods for a sustainable development of the environment as well as concerns which derive from the public awareness and sensitivity about the urban or rural growth. The combination of multiple parameters, methods and decision making techniques, creates the foundation for a Multi-Criteria Spatial Decision Support System. (Athina S.,et al,). Spatial multi criteria decision problems typically involve 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 (Jankowski, 1995; Malczewski, 1996). Spatial multi criteria analysis requires information on criterion values and the geographical locations of alternatives in addition to the decision makers' preferences with respect to a set of evaluation criteria. This means analysis results depend not only on the geographical distribution of attributes, but also on the value judgments involved in the decision making process. (James C. Ascough). Multi criteria decision making (MCDM) can be explained generally as a tool for assisting the decision maker in deciding on the best alternative from all of the possible alternatives under the presence of multiple choice criteria and diverse criterion priorities (Gamze Z. D., et al,). Much of the use of GIS in planning assumes use of a rational mode of decision-making, which entails a linear process initiated with the identification of a problem, followed by a comprehensive search for

alternatives and concluded with the selection of the optimal alternative as indicated by the gathered information, (Batty, 1993)

RESEARCH GOAL

The main goal of this study is to use Arcgis9.2 software with spatial analysis support system for route planning that can be used as a tool to select the optimum route based on multi-criteria approach. The GIS software is flexible to accept different data sets, accommodate different suitability criteria, work with different criteria weight, and define different land use types. GIS can help to improve the quality of decision making through increasing the capacity of analysis, display and management of data. So the objectives of the study are;

- To define the appropriate alternatives for Alkadomiyah and Algria'at future transportation systems.
- To find out an optimized route to travel between Alkadomiyah and Algria'at in each time interval, which give the minimum travel expense (including cost of travel time) by using ArcGIS program based on multi-criteria approach.

STUDY AREA AND DATA COLLECTION

This paper describes an attempt for route planning using spatial analysis. The objective is to help decision makers and planners to find the optimum location of the route through a quantitative spatial evaluation and verification process. The study investigates the options for site selection of a route in a framework of a given decision rules. In this paper, ARCGIS program is used for digitizing, while Satellite image were projected in Geographic Coordinate System (WGS 1984). Then, the maps were digitized by the drawing tools of ARCGIS. The result of digitizing is a digital map in vector form. The study location is Alkadomiyah and Algria'at which represent two parts in north of Baghdad. Alkadomiyah lies approximately (44.389, 33.387) from east and (44.306, 33.388) to the west. Tigris River forms the boundary of the Alkadomiyah from west, while the east for Algria'at. Study area was approximately 34.5km^2. The western side is importance to traffic operation due to traffic attraction because the existing of religions places, as well as it, connects of the main entrance of Baghdad from the north. The previous studies (Scott Wilson, 1985) have estimated the number of daily trips for the year 2015 of about 757263 which is higher as compared to the side of Algria'at which is forecasted to be (15610 person's trip/day). Figure (1) shows the location of the region area.

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Figure 1: The Location of the Study Area

Land Use

The land-use map was obtained from Design Office-Amanat Baghdad, which classified into eight different classes. The different land-use classes were used to present the different terrains over the area of study and these was used in the final judgment for the best alternative to select the best route path. Land-use map include 13.89% open area, 30.96% agriculture, 39.58% residential, 5.42% administration, 4.48% industrial, 3.37% commercial, 1.4% utility, 0.9% transportation. Figure 2 shown the land-use map over the area

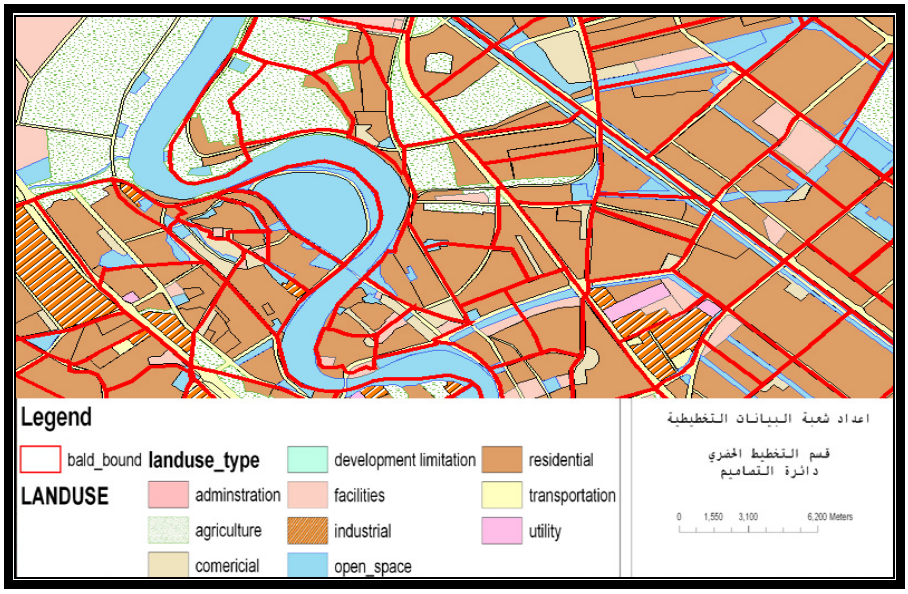

Figure 2: Land Use of Study Area

Digital Elevation Model (DEM)

A digital elevation model (DEM) used to represent a ground surface or a terrain. DEM is downloading from Global Mapper and present the elevations in a form of raster. This model required variety of applications and in most cases are common basis for digitally-produced relief maps that are used in geographic information systems (Gallant & Hutchinson, 2006). DEM of the study area is shown in Figure 3

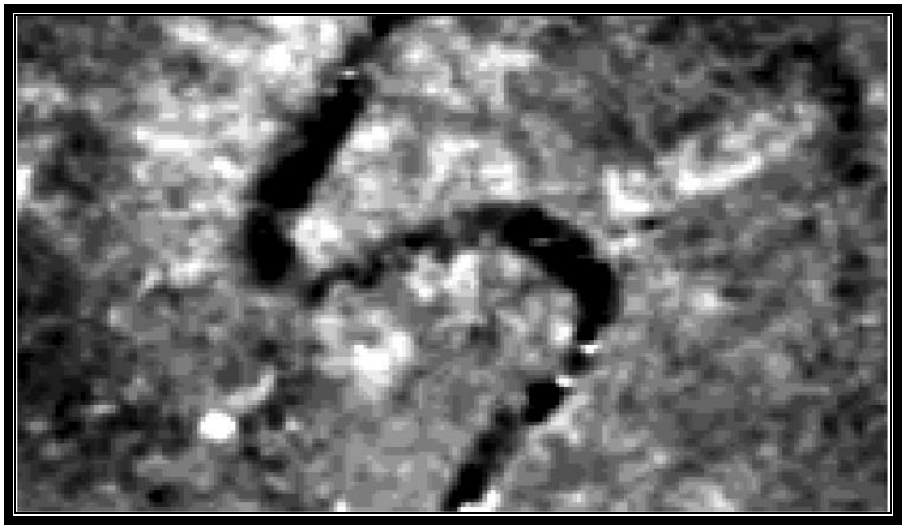

Figure 3: Digital Elevation Model (DEM) of the Study Area

Geotechnical Consideration

Soil Surveys for highway construction entail the investigation of the soil characteristics on the highway route and the identification of suitable soils for use as sub base and fill materials. Since the soil conditions may significantly affect the location of the highway. A detailed soil survey is always carried out on the final highway location, (N.J.Garber, et al, 2002). When new bridge constructed, it must be constructed to support structures under lateral and vertical loads. Vertical load-bearing capacity of bridge depends mainly on site conditions, soil properties, if the soil is of adequate strength, the footings will distribute the loads over a sufficiently large area. If not, the footings themselves must be supported on pile foundations extended down to a firm underlying stratum, which will be then increase cost. The properties of soil are important to identify the process of route selection. The soil map of the area was obtained from National Center for Construction Labs in 1986; it is digitized as shown in Figure (4) and used for producing desired maps for soil classification.

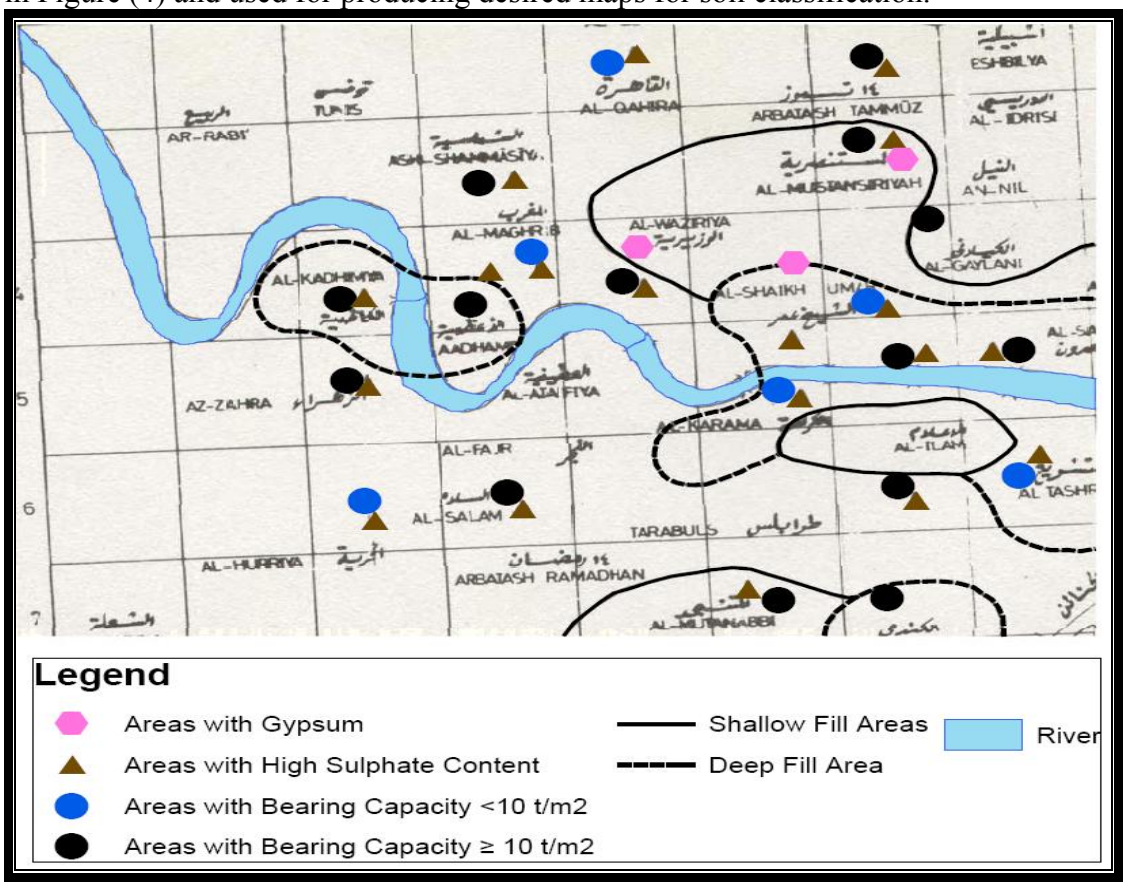

Figure (4) Soil Properties of Study Area

Environmental Consideration

Construction of new route is critical issue due to its side effect on the environment. New route construction or expansion project is one of the main sources that damaged the environment (Raeid Al-Sadeq,2006). It is very important to consider the impact of the project on the environment. Due to lack in such data for our case study the environmental factor cannot be considered. In general the environmental factor plays an important role to select the suitable alternative especially in the large study area. In this case, due to the limited study area and the similarity in the environmental impact, the weight of environmental effect can be ignored. This opinion matches the results of expert transportation questioners.

RESEARCH METHODOLOGY

ArcGIS Spatial Analyst provides a broad range of powerful spatial modeling and analysis features. Using ArcGIS Spatial Analyst, GIS users can create, query, map and analyze cell based raster data; perform integrated raster/vector analysis; derive new information can derive information about geospatial data such as terrain analysis, spatial relationships, suitable locations, and the accumulated cost of traveling from one point to another. First, land use and road network in object area are digitized into ArcGIS9.2 software. Topology of road network and division of traffic analysis zones are done in the database. Second, attributes of links, is input and such as lane division, capacity and speed in the network are surveyed and collected. In this method, taken construction costs, economic and geotechnical aspects into account when deciding a new highway location in road network. Then subject to the control points to location different alternatives for the new path. The study's main goal is to identify the most suitable areas where new route can be established. This will be achieved through the ESRI's Model Builder environment. The framework for the model includes the problem definition, the criteria selection, the parameters' weighting, the spatial analysis implementation, the illustration and inspection of the selected areas, and finally the recommendation of the most suitable areas (Malczewski 1999). In this case study, analyses are carried out on one growing centers in the religion city of Baghdad. The selection of the research area is based on the demand of Algria'at that needs to be added and extended to populated area. In addition, the land use meets the criteria for new route. Since the location of the case studies, Alkadomiyah and Algria'at, are adjacent it will be practical to integrate the allocation of route alignment in these two areas. There are four main stages involves in the implementation of this research, which are:

Stage1: Identifying the objectives and evaluation criteria
Stage2: Implementing the multi-criteria analysis,
Stage3: The generation of alternative route
Stage4: Evaluation and selection of route

A new raster-based GIS model that combines multi-criteria evaluation and least-cost path analysis was developed to determine the optimal routes.
The analyst might take the following steps
1-Identify the relevant map layers
2-Reclassify maps to indicate good or bad area
3-Perform a weighted analysis on the map layers
In this implementation, the best route is found. The steps to produce such a path are outlined below and shown in Figure 5. Path is performed using ArcGIS 9.2 Spatial Analysis Module.
1- Create Source, Destination and Cost Datasets
2- Generate A Thematic Cost Map (Classify and Weighting)
3- Perform Cost Weighted Distance
4- Create Direction Datasets and Perform Shortest Path

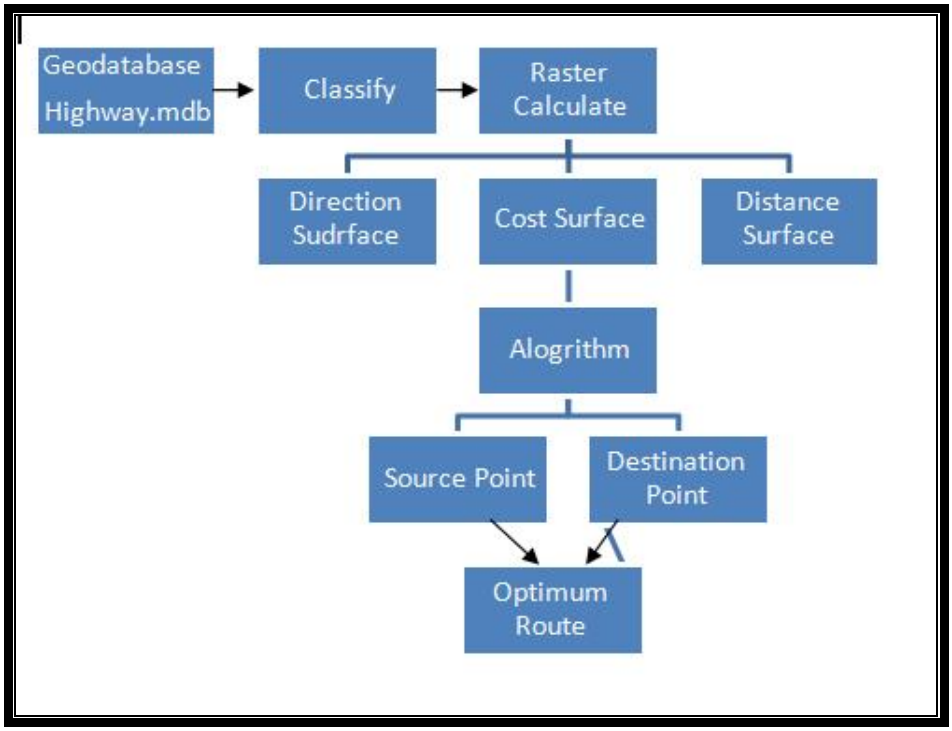

Figure 5: A conceptual model for optimum route

The model logic can consider multiple criteria simultaneously (i.e. land use, elevation, distance and soil effect). Digital Elevated Model (DEM), land use and soil layer data are overlaid in GIS using weight output from AHP to generate cost dataset, so all processes are made on raster format. The start and destination points for the road path was created using ArcMap9.2. The re-classed map helps to differentiate a bad from good areas to build a road path. In the classified map, 1 value was used to represent good areas with low cost value to build a road while 10 represent bad, which is a high cost to build a road. Reclassified map for land use, slope, and soil are shown in Figure (6), (7). In this model, calculate the distance as shown in Figure (9). Four alternative paths are investigated as shown in Figure 10. The benefits of a conventional decision support system are combined with the flexibility and the scalability which is offered in a spatial analysis model, developed on ESRI's Model Builder environment to select the optimum route and is shown in Figure (11).

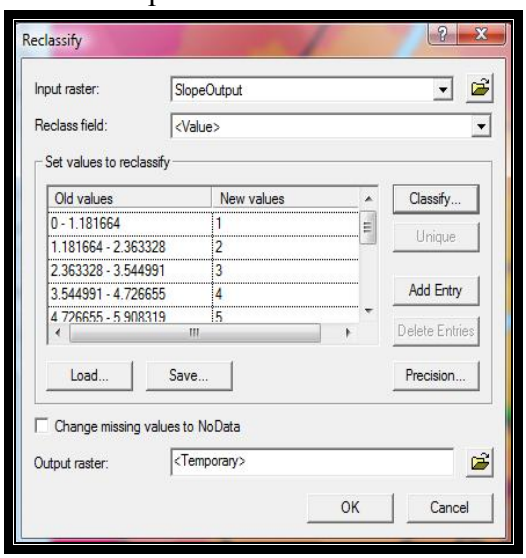

Figure (6) Reclassified Map of Slope Output

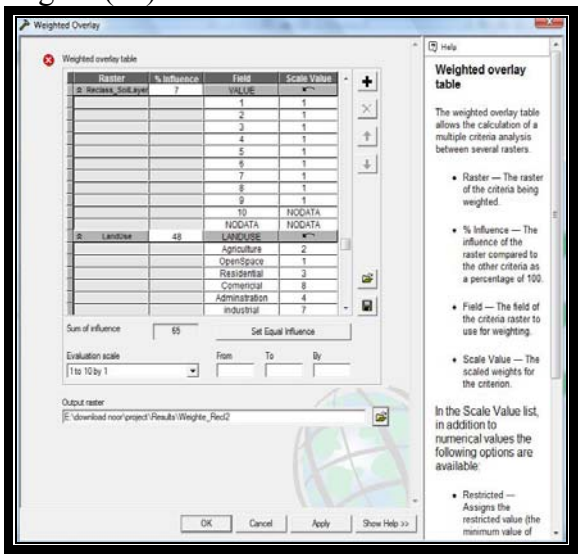

Figure (7): Reclassified Values of Land Use and Soil Layer.

Application of the Analytic Hierarchy Process (AHP)

AHP is a multi-criteria decision method is used for representing a problem by using hierarchical structures and then for developing precedence for alternatives according to the decision maker (Saaty, 1980). It has been shown that hierarchical structuring and pair wise comparisons are used for weighting activities by Saaty (Saaty, 1980). There are AHP scales for pair comparisons. These scales are used in calculating weight for each layer. Pairwise Comparison Method (PCM) has been used to determine the comparative weight of each parameter. The number of route selection criteria is set in AHP to derive weight for each criterion as shown in Figure (8). To prepare the preference matrix, the nature of the study area should be considered. Accordingly, the soil properties and the slope represent minor effect while, route length and land use represent major effects on the preference matrix.

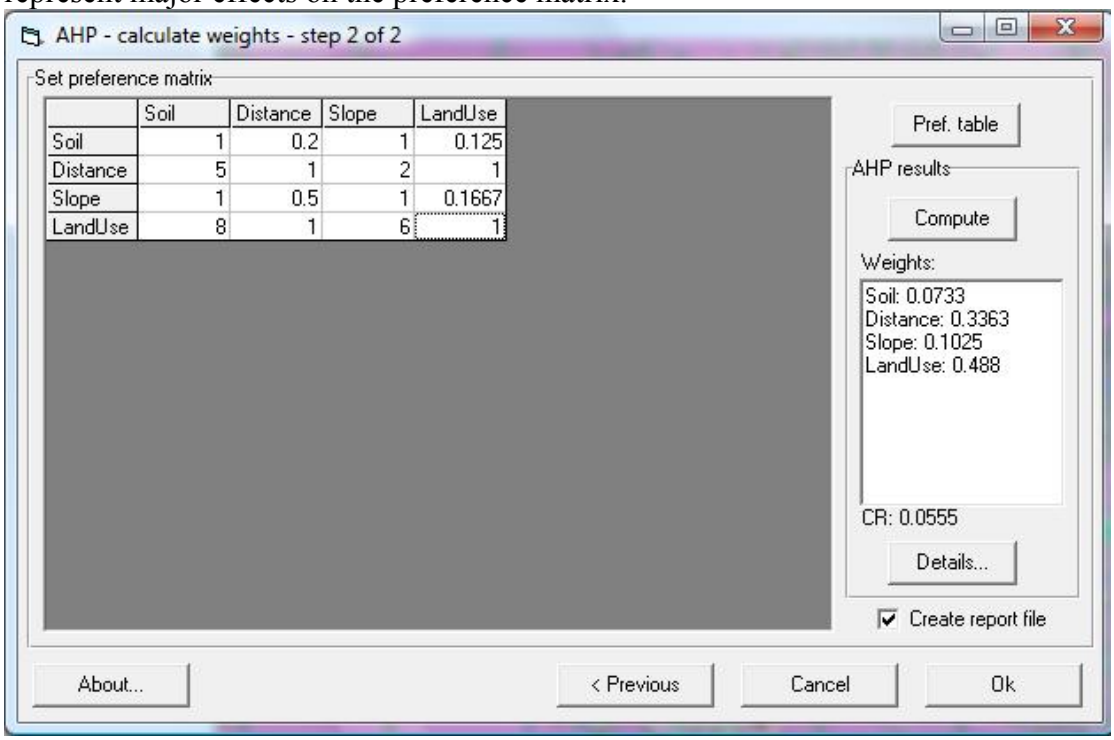

Figure (8) Application of AHP to Derive Weight

Selection of the Preferred Alternative

After identifying the alternative sites, selection of the most appropriate site can be made by consideration of multi-criteria imposed by the user. Multi-criteria decision aid supporting the choice among a set of alternatives described by values for criteria. This study has selected four types of routes in generating alternatives. Using spatial analysis model, all four types of routes will be evaluated against the set criteria in order to selecting optimum route. It is important to note however, that the analysis need to provide the capability to maximized the output to connecting strategic locations and maximizing network. The four proposed route alternatives are evaluated on the basis of the four criteria discussed above. Decision rules provide the basis for sorting and ranking the decision alternatives under consideration of route attributes and user preferences (Malczewski, J, 1999). The application of final step for Multi-criteria procedure can be presented below by the cross-table of criteria and alternatives. The decision maker selects the suitable score for each cell in the mention Table (1). The normalized sum computes the sum of all factors for each alternative. Which, the higher values are preferable than smaller values in selecting the preferred alternative.

Table (1), Summary Table of Alternative Route Characteristics

Criteria Type	Path1	Path2	Path3	Path4
Geometrical				
Length	10	9	6	5
Crossing	9	4	4	9
Curvature	5	4	3	6
Maximizing road network	6	4	9	7
Grade	N.E	N.E	N.E	N.E
Geotechnical				
Bearing capacity	N.E	N.E	N.E	N.E
Social				
Population Density, Urban Area	5	6	7	7
Economic				
Construction Cost	8	8	4	4
User Cost	8	8	4	4
Maintenance Cost	8	8	4	4
Land Use	6	7	7	6
SUM	65	58	48	52
Normalized Score	29.1%	26%	21.5	23.3%

- N.E. (Not-Effective), this regarding the nature of study area.

In Baghdad city, the bearing capacity of soil seems to be similar. Accordingly, the geotechnical factor will be not effective in this case. It is important to mention that the scoring weight which present in Table (1), was prepare by considering the transportation experts opinion.

Selection of the preferred alternative was based upon a review of the impacts identified as shown in Table (1). Accordingly, Alternative (1) is selected to represent the optimum path based on multi criteria evaluation.

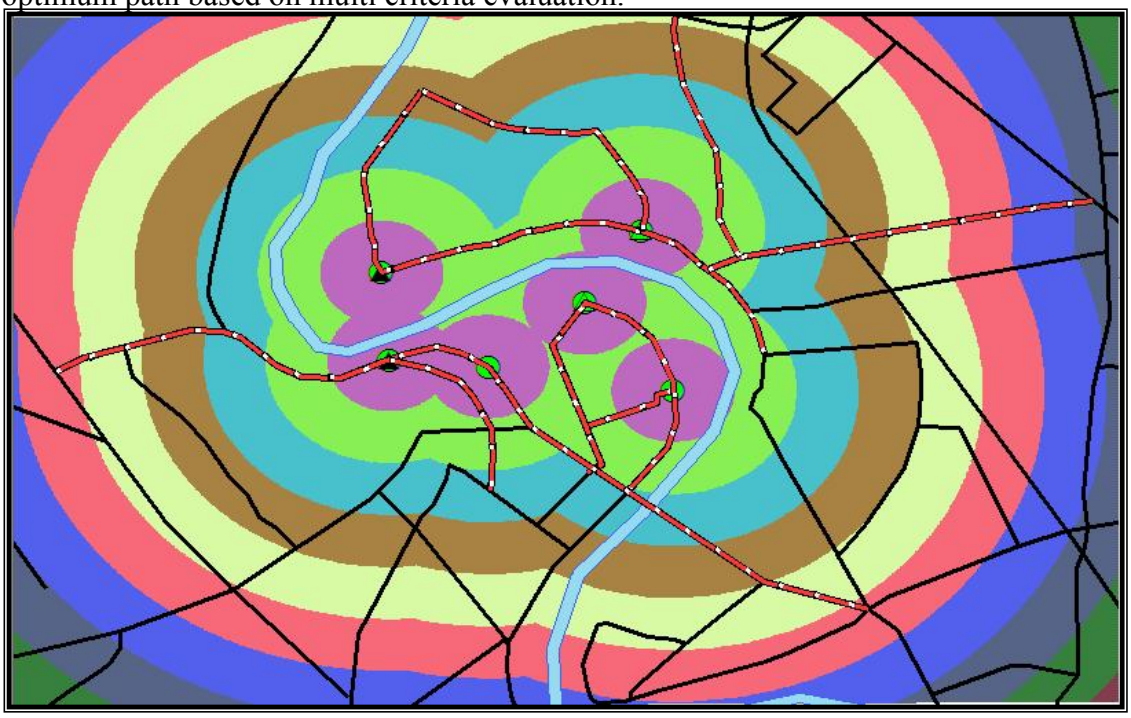

Figure (9): Reclassify Distance for the Selected Control Point

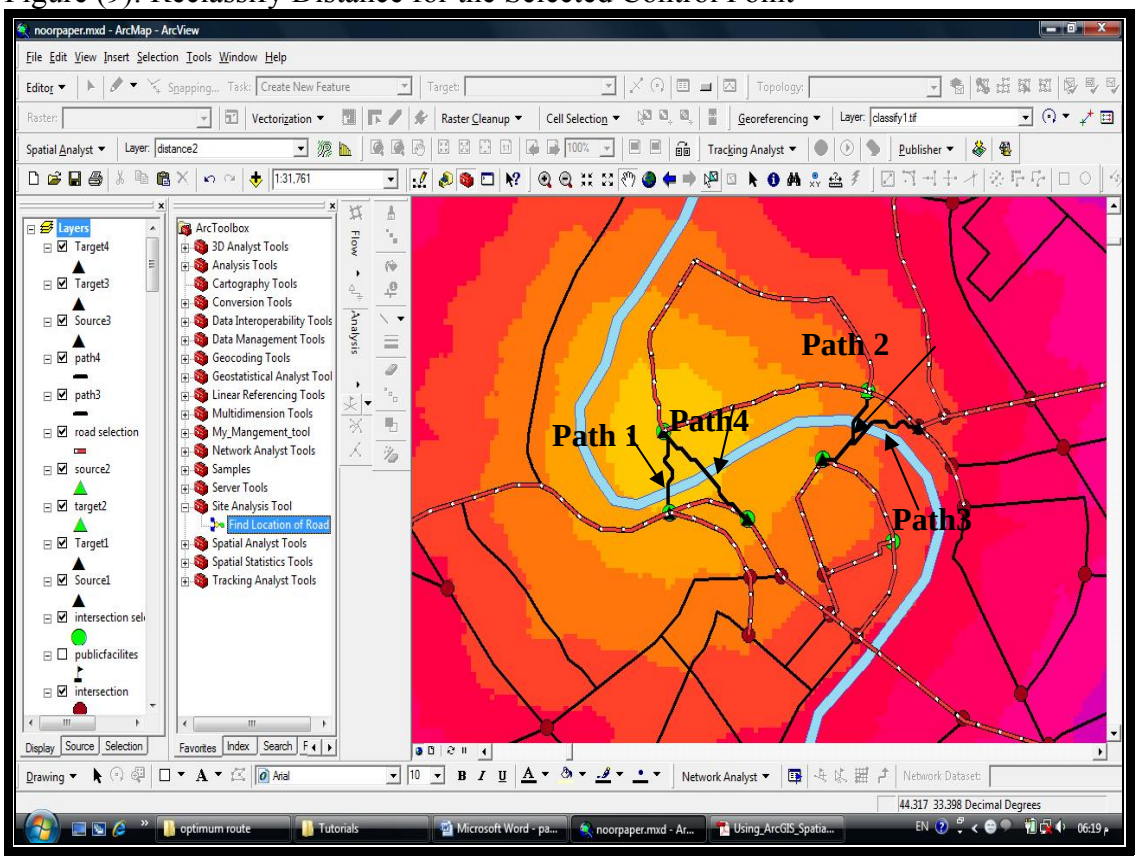

Figure (10): Alternative Route Path

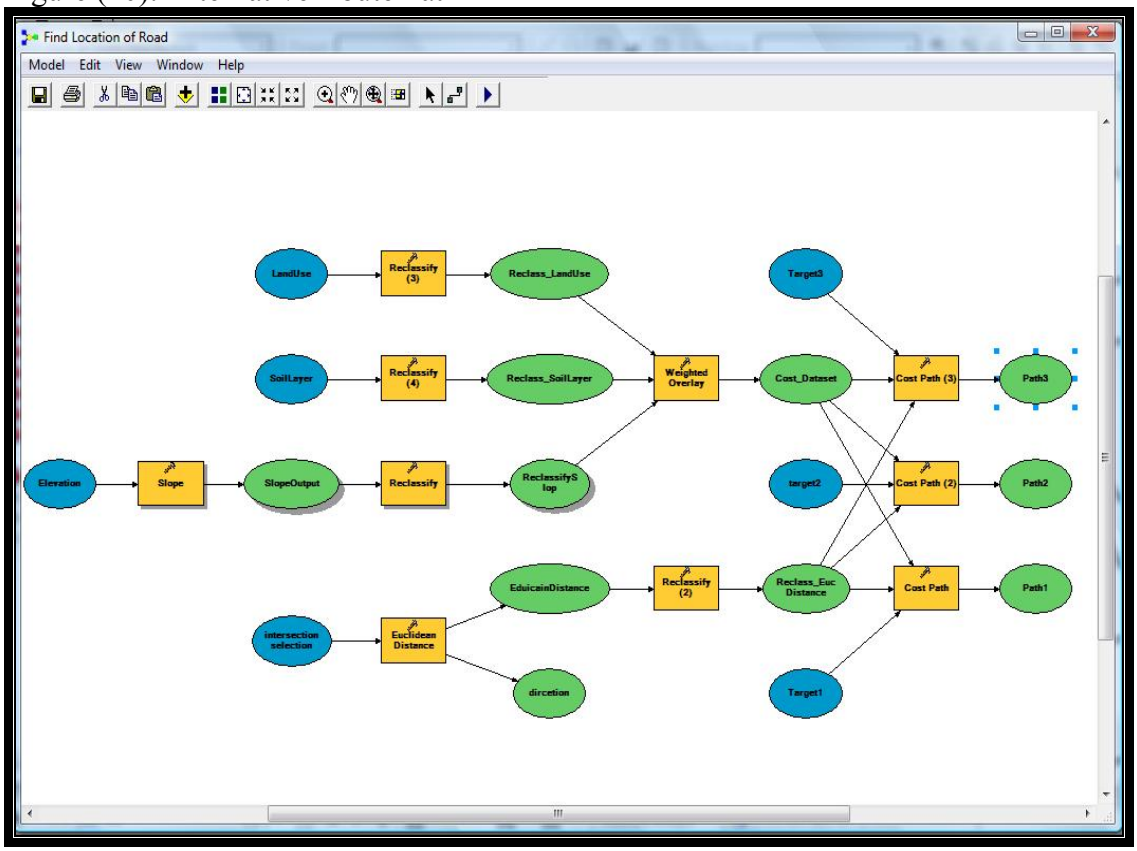

Figure (11): Model of Shortest Path

RESULTS

Based on GIS application in transportation planning, AHP is used in weighting of different effective factors in the proposed criteria, ArcGIS 9.2 Spatial Analyst module is applied in the optimum route selection. The present study investigates how non-spatial and spatial data can be integrated within a multi criteria decision framework to formulate and select best suitable route. Accordingly, and regarding the present case study, alternative (1) was proposed to be selected as a best route to connect Alkadomiyah and Algria'at in Baghdad city. The selected roadway is started on the origin of an approximate coordinate of (44.337, 33.394) and the destination of an approximate coordinate of (44.337, 33.388), with 0.7 km length. The GIS based analysis as applied on the present case study demonstrated that; multi-criteria approach is recognized to be used as a tool for the optimum route selection by considering different factors those affecting decision-maker selections. Furthermore, saving of money, time and effort. Finally.

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