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GIS Based Multi-Criteria Decision Analysis for Locating Bank Branches

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ABSTRACT: In banking industry, optimum location of the bank branch plays an important role in ensuring the success of the bank. It is one of the most important decision making processes. This issue is highly important because of the vibrant competition, limited budgets and high customer expectations .This study's objective is to provide a hybrid model for selecting optimal site location using available data sources and well accepted decision models, specifically Analytic Network Process (ANP) and Geographic Information System (GIS).The process identified the most commonly used criteria for bank branch location consideration through literature review yielding demographics, competition, transportation, access to public facilities. Criteria and sub-criteria weights were quantified through pair-wise comparison using expert judges, via ANP. The database created for the study area (Khartoum Locality) includes data about demographics, competition, transportation, access to public facilities available in the area. With the help of Esri's ArcGIS software through using the weighted overlay analysis tool we have identified suitable sites of new bank branches .The results showed five optimal locations for new bank branch in Khartoum locality; location near Madani St, location close to Bashir Elnefedi St, location at Firdous East Square 8, and two other sites in Khartoum West (Shajra Avenue).
For the conclusion, these results show the efficiency and applicability of the proposed integrated method.

KEY WORDS: Bank Branch Location, GIS, Multi criteria Decision Analysis, Site Selection Criteria.

INTRODUCTION

Recently, banking services have witnessed substantial developments which lead to changes in the organization of banks. Competitive environment of banking industry results in a more convoluted location network of bank branches [1].In addition, growing information technology and widespread usage of online banking makes the decision of bank branch locations a more significant and complicated task for banking professionals [2]. [3] Revealed that bank branches' location has a great influence on deposit amounts, and subsequently on banking profits .Recent papers such as [4], [5] have studied the impact of the growth of large banks on bank performance and profitability .Location selection is clearly very important for banks because it can be a very costly mistake, specifically if the decision problem is related to locating many branches, resulting in a unnecessary moving cost, lost endeavor, lost competitive advantages and so on as [6] have pointed out, "In the development of competitive strategies, prices can be matched, services can be extended and improved, but a retailer's location advantages are difficult to assail or neutralize .The purpose of this study was twofold. One goal was to generate site suitability map for bank branch location in Khartoum city. Another goal was to identify and determine the criteria of bank branch location through literature review and discussion with bank managers. In this study, we focus on generating suitability map and evaluate the present situation for a bank branch in a study area. This study is organized into five sections. The first section discusses previous studies that dealing using GIS In location suitability and discusses background about MCDA (ANP) in suitability analysis. An introduction of the study site, description of the data sets and factors used in the model are provided in Section 2, and illustration of the methodology is provided in Section 3. Section 4 presents the results of the study. Finally, a conclussion and recommendations for future work are presented in the final section.

BACKGROUND LITERATURE REVIEW

Literature Review

A great number of studies have utilized Geographic Information Systems (GIS), Decision Support Systems (DSS), andOptimization problems separately and collectively in location selection problems. For example:[7] Formulated the problem of determining

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the optimal location of bank-branches by sequentially dividing the process into three stages; planning, implementation, and decision stage. They used spatial modelling and Euclidean distance methods to reach the desired decision.In another study, a hybrid methodology of the analytic hierarchy process (AHP) and VIKOR (VIsekri- terijumsko KOmpromisno Rangiranje) was introduced to solve the plant location selection problem [8].[2] Formulated the problem of determining the optimal location of bank by Analytic Hierarchy Process (AHP), Geographic Information System (GIS) and Maximal Covering Location Problem (MCLP).In 2005, the analytic network process (ANP) was employed to select the best location for a shopping mall [9].In research article, FUZZY AHP and FUZZY TOBSIS was applied in Mehre Eghtesad Bank(Iran) to select a proper location for opening of new branch, leading to increase of costumer's satisfaction, market share growth, profitability, and reduces the cost. Fuzzy AHP was used to contribute to the human judgement in decision-making. TOPSIS technique is applied to obtain the best option close the positive ideal solution maximizes the profitability criteria and minimizes the cost [10].

Study Area

The city of Khartoum is located in the heart of Sudan, at the confluence of the White Nile flowing north from Lake Victoria, and Blue Nile, flowing west from Ethiopia which combine to form the River Nile. This research focuses of a site suitability analysis for bank branch location in the Khartoum locality (Figure 1). The locality of Khartoum is situated on the south and west bank of the Blue Nile and the east bank of the White Nile with a population of about a 4,229,432 million inhabitants as of 2012.

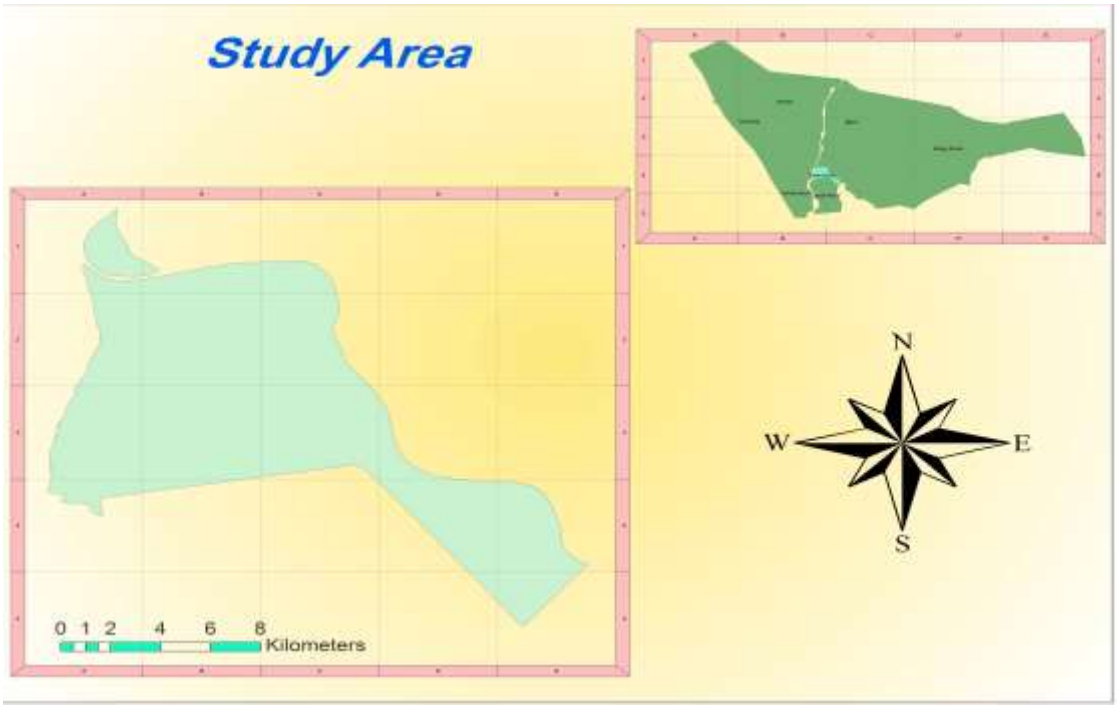

Figure 1: Location of study area.

Data Sources

The main source of information is the available maps, data collected from Google earth pro and Open street map as show below (Table 1):The primary data were collected through interviews and questionnaires answered by experts in the banking industry for identifying factors that are important for the location of bank branches. Global Positioning System (GPS) field survey data and other GIS datasets. The GIS based land suitability analysis has been applied in a wide variety of situations including sites and administrative boundaries.

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Table 1. Dataset information

Number	Dataset	Description	Source
1	Khartoum map	Polygon as a feature class	2015 Ministry of planning and Infrastructure (Sudan)
2	Branches of the banks in Khartoum Locality	Feature class representing point Locations of bank branch buildings	Central Bank of Sudan
3	Population Density	Polygon as a feature class	Sudan Central Bureau of Statistics
4	Road Map	Feature class representing the linear roads of Khartoum locality.	openstreetmap.org 2016 www.openstreetmap.org
5	Public Facilities	Feature class representing point Locations of facilities buildings	Google Earth Pro 2016

METHODOLOGY

Figure 2 shows the framework used in this study and methodology. The framework integrates the ANP methodology with GIS techniques. It can be subdivided into four major steps: (i) the problem definition/ criteria identification, (ii) data input (iii) ANP procedure, and (iv) GIS implementation.

The Problem definition Criteria identification and selection.

The first step in the bank branch location problem is to define the problem by developing a conceptual model for the decision/evaluation problem. This is the central part of the qualitative component of the ANP as this conceptual model drive all succeeding works for solving the decision problem. It is important to have a clear starting point with specific goals and objectives. In general, bank branch location problem involves choices among criteria (factors). Once the goal is defined, the next step is to identify and select the criteria to be used for the assessment. Criteria identification can be done through experts identifying the factors and/or through literature search to find the factors used by previous studies and selecting those that are applicable to a particular case study.

Firstly, the criteria and sub-criteria for the selection decision were identified through the studies of the literature, specifically [1],[11],[12],[13],[14],[2]. For example, Population density, growth potential, income level, competitive situation and number of firms in the candidate districts were used by [11], [14] and [12] to decide the location of bank branches. Additionally; access to public facilities, demographic characteristics, and road networks, position of competitor banks and easement of access were considered in [15]. Eight sub- criteria in four main categories were obtained as relevant to the study. Weights of criteria and sub-criteria were determined via pair-wise comparison via ANP questionnaire involving 20 managers of banks with at least 3 years of working experience in different branches of bank (Located in Khartoum City, Sudan).

Table 2. Criteria and sub-criteria of bank branch location

Main criterion	Sub criterion
Demographic (C1)	Population density (SC1)
Competition (C2)	Proximity to the existing branches of the bank (SC2) Proximity to branches of competitors (SC3)
Transportation (C_3)	Proximity to squares, junctions (SC4) Proximity to the main roads (SC5)
Access to public facilities (C_4)	Proximity to public parking (SC_6) Proximity to market centers (SC_7) Proximity to hotels and restaurants (SC_8)

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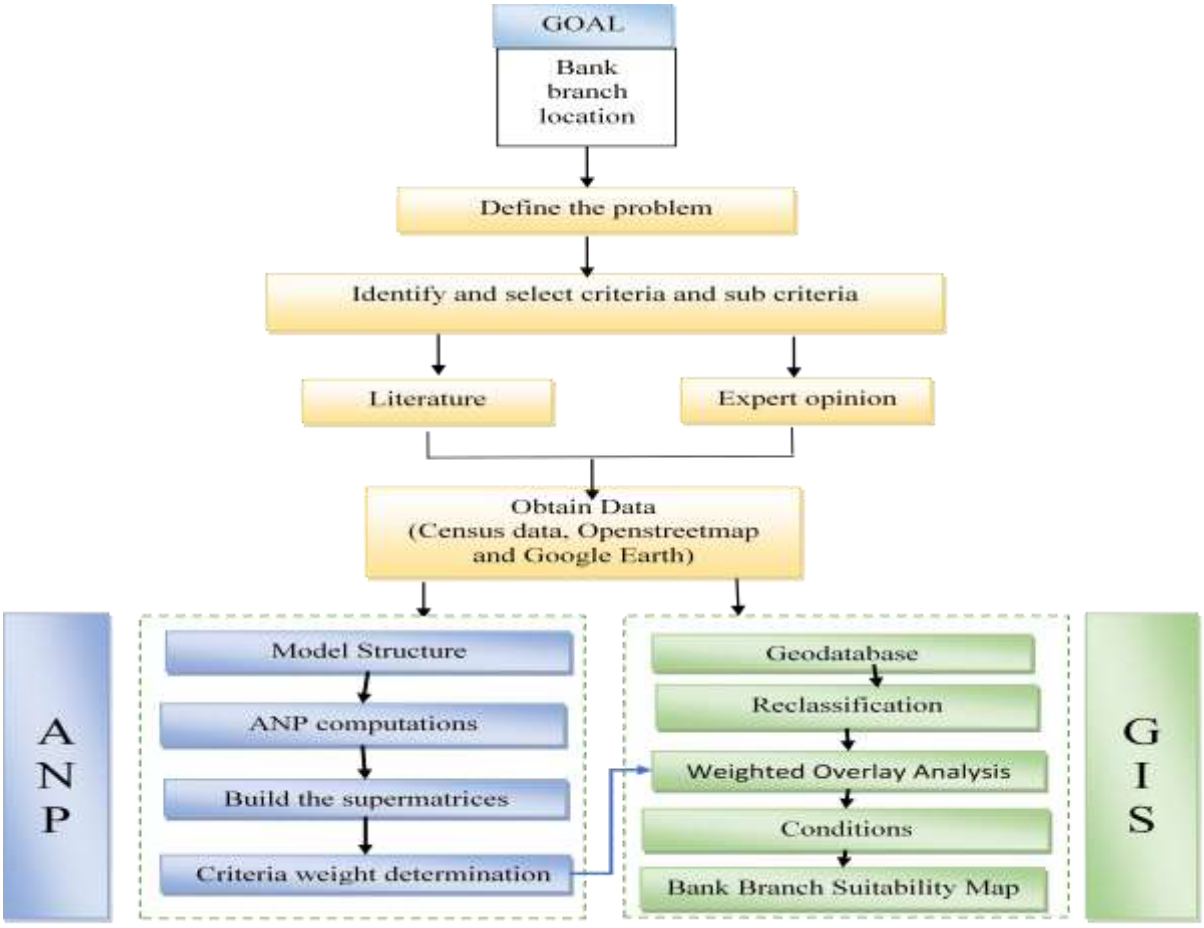

Figure 2: Methodology of the study.

Data input

After the criteria has been selected, the next process is to acquire the relevant data needed for the decision problem. The datasets can be obtained from census data and central bank of sudan or through Google earth pro and Open steetmap. Preparation and classification of the obtained data is carried out for the ANP model (adaptation of the data to the necessity of the ANP model).

ANP procedure

The ANP procedure is adopted for obtaining the criteria weights (see Section 3.8). The ANP computations will be performed using the Super Decisions software and the results transferred into GIS. The ArcGIS 10.4.1 software will be used.

Determination of Weight Value for Each Criterion Using ANP

In the context of bank branch location, the goal of the decision/evaluation problem is to rank and weight the relative importance of the criteria and sub criteria.

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Table 3. Final priorities of the criteria

Category	Criteria	Priority	Rank
1	Access to public facilities	5.9%	4
2	Competition	26.3%	2
3	Demographics	53.5%	1
4		14.3%	3

GIS implementation

The main goal of the Bank is to provide bank branch at the nearest site for the target customer segments. The following criteria are used according to their relevance of the research objectives which are Demographics, competition, access to public facilities, Transportation or traffic system. These aspects were kept in mind for our analysis. Different features like bank branches data and public facilities captured from Google earth pro in KML format are used, after converting into the shape file format. Furthermore, road features captured from Open Street Map in OSM format are used as well, also in shape file format. For carrying out this analysis 'finding the best location for new bank branches' a model was built in ArcGIS to do some Geoprocessing. Geoprocessing is a method that allows to chain together a sequence of tools, feeding output of one tool to another. Alternatively, it can be defined as a process to automate the workflow (Figure 3). The Criteria for selection of optimal sites for bank branches are as follows:

- The site should be in close proximity in dense populated areas.
- The site should be near to facilities.
- Area surrounding the site should be as far as possible from existing bank branches whether they are owned by the competitors or by the bank itself.
- It should be in close proximity to major roads, considering customer's safety and convenience.

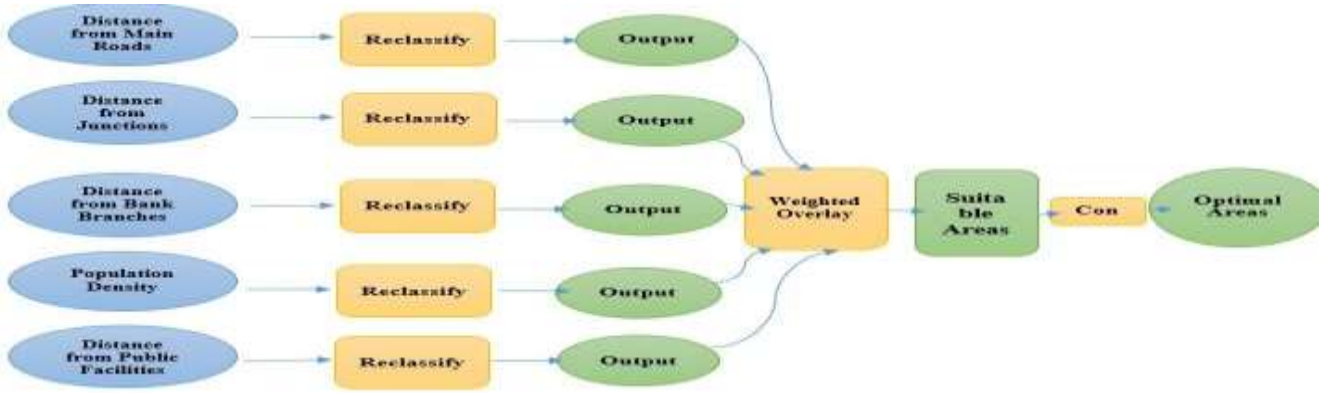

Figure 3: Model Builder (Finding the best Location for new bank branches).

RESULTS AND ANALYSIS

The study has four different main criteria (demographics, competition, traffic system, and access to public facilities). This was done in order to simplify the analysis of the final judgment between the four layers thus resulting in the creation of the suitability layer that used to determine the optimum location that a bank branch can be established.

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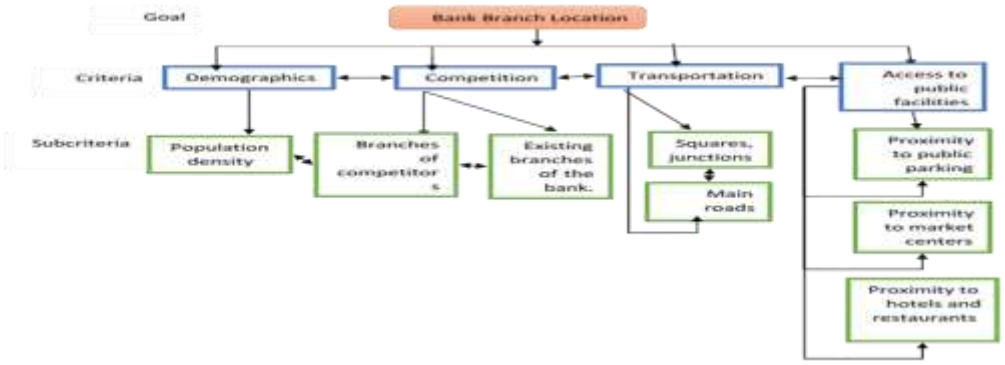

Figure 4: General framework for Bank Branch Location Selection

Figure 5 shows a present scenario of Khartoum Locality (Study Area). It contains the main layers of the study which are Access to public facilities, competition, Demographics, and Traffic system of the city. These layers are representing the important data for this research.

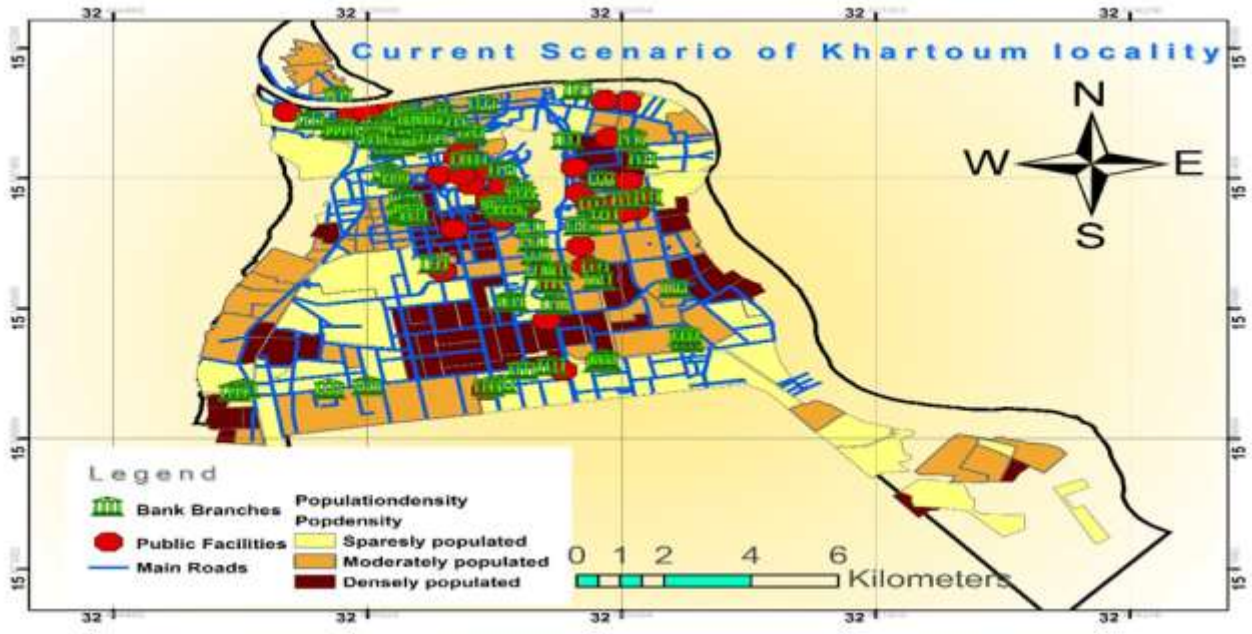

Figure 5. Present Scenario of Khartoum Locality

Spatial Analysis

The study used ArcGIS spatial analyst (ArcGIS 10.4.1) to find a site for a new branch. For implementing this analysis, it is better to build a model that finds suitable locations for a new branch. The steps to produce such a suitability map are outlined below.

Step 1: First a new model is created. A model is built by stringing tools together inside a Model Builder window. Those tools are all in Spatial Analyst Tools toolbox. Now the study start to build the model. For deriving distance from property sites, the Euclidean (straight-line) distance from public facilities must be calculated. This task is done by using the Euclidean Distance tool from Distance toolset in Spatial Analyst Tools toolbox. The distances from existing banks are also required because the location of new bank should be away from those banks. Also the distance from the roads is required because the new bank branch should be located nearer to the main roads.

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Step 2: After deriving the necessary datasets, it is ready to reclassify each derived dataset to a common measurement scale, give each range a discrete, integer value between 1 and 10. Higher values are given to attributes within each dataset that are more suitable for locating the bank branch. The bank branch should be located as close as possible to a property facility. So the distance to property sites is reclassified, giving a value of 10 to ranges of values that represent areas closest to property sites and giving a value 1 to ranges of values that represent areas far from property sites. It is necessary to reclassify the distance to existing banks layer too. A value of 10 to areas farthest from existing banks and value of 1 to areas closest to existing bank branches are given. By doing this the study can find out which areas are near and which areas area far from property sites and existing banks branches. The same procedure for the main roads and junctions is performed by giving a value of 10 to areas nearest to the road and junctions and value of 1 to the areas farthest from roads and junctions. It is also necessary to classify the population density layer by giving value of 10 to areas nearest to densely populated areas and value of 1 to areas nearest to sparsely populated areas.

Step 3: At this moment it is ready to combine datasets to locate suitable sites for the new bank. It is preferable to locate the new branch close to densely populated areas and close to property facilities and away from existing branches and close to the main roads and junctions. The study weight all the inputs and give each input a percentage of influence. The higher the percentage, the more influence a particular input will have in the suitability model. By doing this, the study have used Weighted Overlay tool.

Figure 6 shows the suitable area for the locations of new bank branch after applying step one and step two.
Sites selected by a weighted overlay are having suitability values. The attribute value is assigned from 1 to 10. 1 is the worst and 10 is the best suitable area.

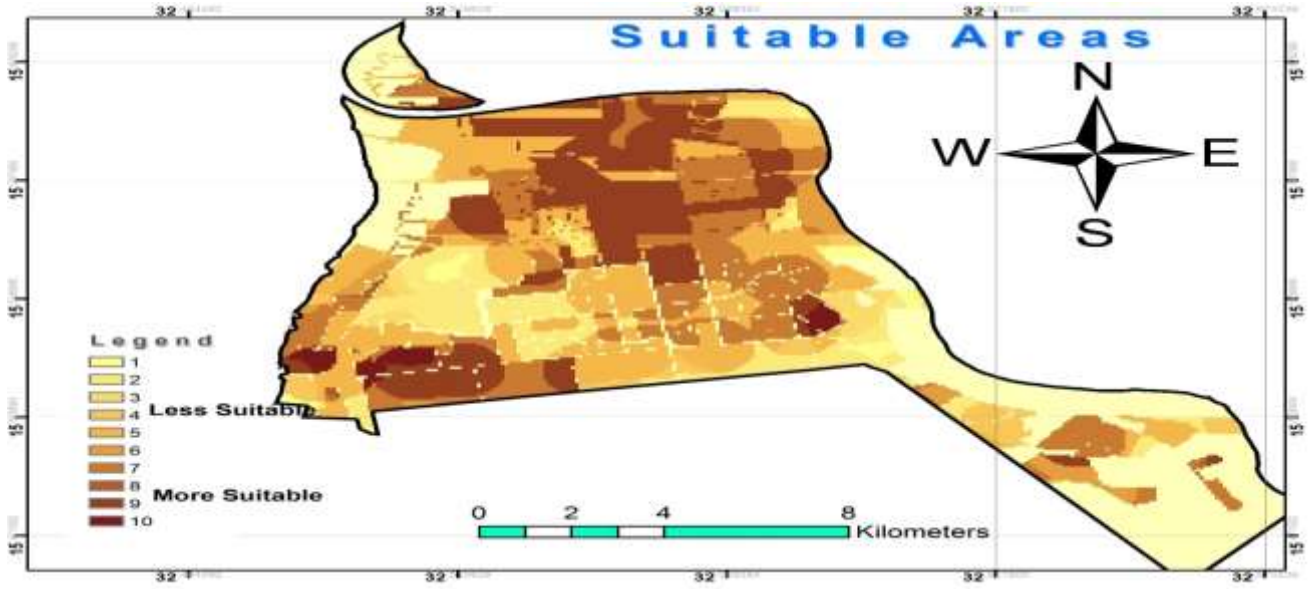

Figure 6. Shows the best suitable area for the locations of new bank branches.

Step 4: Subsequently, the study have used a conditional expression in the Con tool to extract only the optimal sites. The sites that are considered optimal must have a suitability value of 10. In the conditional expression, all areas with a value of 10 will retain their original value (10), and areas with a value of less than 10 will be changed to NoData.

Finally, after performing a multi-criteria analysis using geographic information system five optimal sites for locating bank branches were identified in the extension of the study area (Figure 7). Obviously the optimal of these suitable sites for locating bank branch's is in the areas closer to Madani St and Bashir Elnefedi Street and Firdous East and two other sites in Khartoum West (Shajra Avenue). Because it is compatibility with the chosen criteria.

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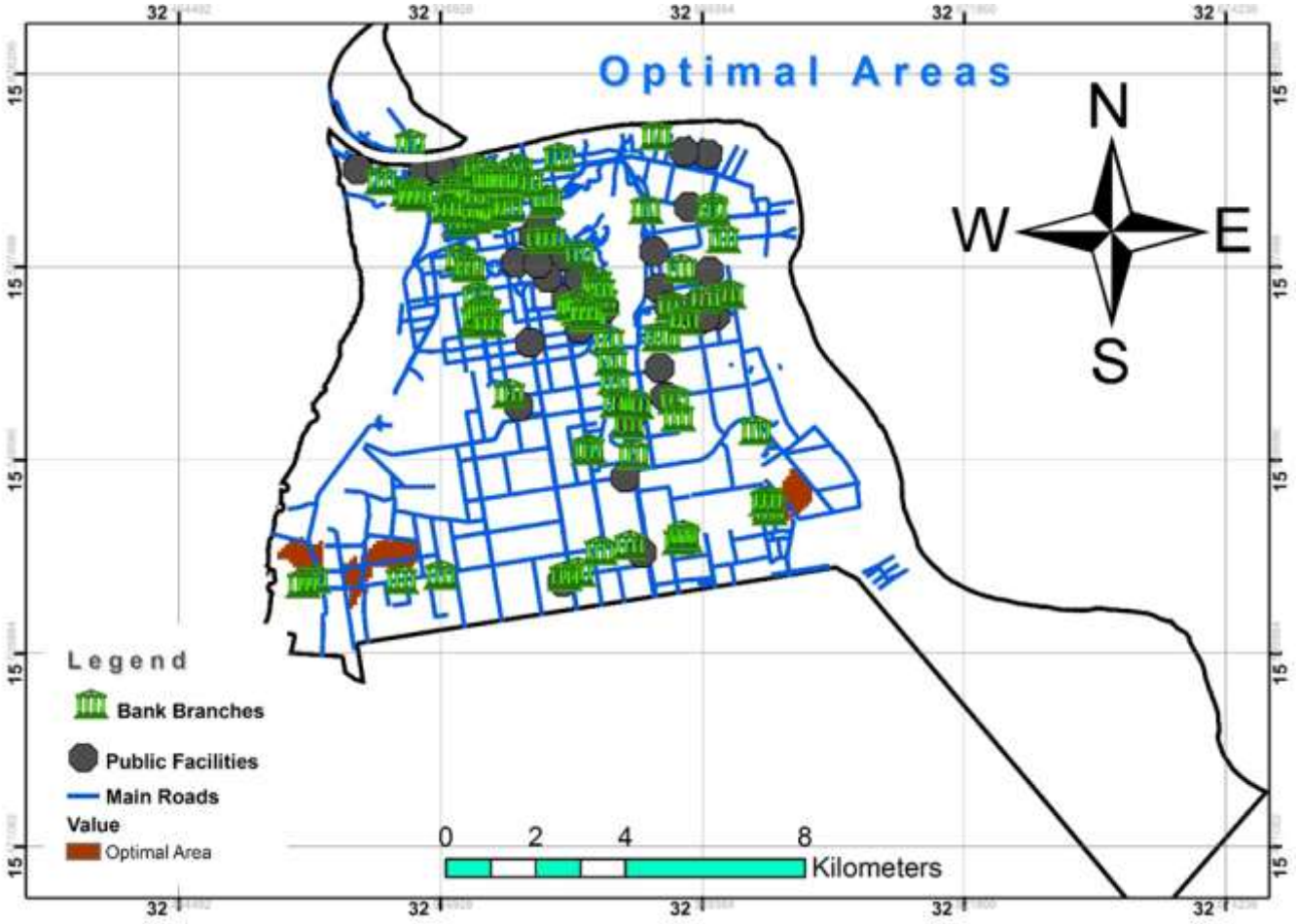

Figure 7. shows the optimal area for the locations of new bank branches.

DISCUSSION

The purpose of this paper was to introduce the applicability of geographic information system (GIS) and Multi-criteria decision analysis (MCDA) to locate the optimum areas that a bank branch can be established in Khartoum locality.

The use of (GIS) in this thesis has helped to incorporate digital layers of different scales and the use of Multi-criteria decision analysis (MCDA) has also facilitated to structure the evaluations to encompass several, often competing criteria in order to identify and rank the most preferred solution in a certain decision context which is location of a bank branch because selection the optimum location of a bank branch is complex and presents number of challenges. The level of the complexity in the planning process comes from the consideration of different factors, which must be considered in the analysis. In order to make sound decision making in locating bank branches where it is needed the most, it is essential to determine the relative importance of the considered criteria. There are numerous considerations in determining criteria and selecting methods which all depend on the trade-offs between: ease of use, accuracy, the degree of understanding on the decision maker, the theoretical foundation underlying that method, the availability of computer software, and method can be incorporated into GIS-based multi-criteria decision analysis. In this thesis the Analytical Network Process, which uses a pair-wise comparison matrix, was used to determine the relative importance of the parameters. Empirical applications suggest that the pair-wise comparison method is one of the most effective techniques for spatial decision-making, including GIS-based approaches.

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CONCLUSIONS

In this paper, a hybrid model of ANP-GIS was proposed to determine optimal locations of new bank branches. This method used ANP to find the weights of criteria and sub-criteria of locating bank branches which are demographics, competition, transportation, and access to public facilities as a main criteria. Criteria and sub-criteria relevant data were extracted from Google earth pro and open street map to obtain layers of information for different regions of Khartoum city. From this project we also learned that integration of geographic information systems and multicriteria decision analysis techniques such as analytic network process can play a great role in finding the best location for new bank branches. This task has been achieved successfully by considering the customer as a center of activity, then the facilities offering money and other services, while also keeping in mind the road network of the city as this the most important means of bank services and ultimately for the benefit of a bank.

Bank branch location modeling give us an advantage and put a decision maker in a good position to decide about the best location, when he needs to build new bank branches. We have demonstrated by simulations that we can predict the potential bank branch areas, which means that we can take a decision before a bank branch is finally built.

RECOMMENDATIONS

The following recommendations are offered as possible ways to improve this study.

1. For future research, other MCDM methods such as Fuzzy analysis network which is more advanced and more accurate of ANP can be used to obtain the weight of criteria and sub-criteria. Furthermore, to solve the optimization problem in large scale problem, the heuristic algorithm such as Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) can be utilized.
2. This study provides an insight of GIS-ANP methodology for locating bank branches to improve customer services. It is interesting to further investigate other functions what GIS system can provide in bank developing.
3. Researchers can study and identify the other criteria that are not included in this study and use them in their researches.

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