Sudan University of Science and Technology

College of Graduate Studies

College of Computer Science and Information Technology

Title:

Finding the Best Location for New Restaurant Using GIS Technologies

إيجاد أفضل موقع لمطعم جديد باستخدام تقنيات نظم المعلومات الجغرافية

A Thesis Submitted in Partial Fulfillment of the Requirements of Master Degree in Computer Science

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July 2016

بسم الله الرحمن الرحيم

الآية

قَالَ تَعالي:

﴿اقْرَأْ بِاسْمِ رَبِّكَ الذِي خَلَقَ (١) خَلَقَ الإنْسانَ مِنْ عَلَقٍ (٢) اقْرَأْ

وَرَبُّكَ

الأَكْرَمُ (٣) الذِي عَلَّمَ بِالقَلَمِ (٤) عَلَّمَ الإنْسَانَ مَا لَمْ يَعْلَمْ (٥)﴾

صدق الله العظيم

العلق: ١-٥

Dedication

To my mother, father,

And all of my beloved friends,

Without whom none of my success would be possible

Acknowledgements

Firstly, I would like to express my sincere gratitude to my advisor Prof. **Dieter Fritsch** for the continuous support, for his patience, motivation, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for my master study.

I thank my fellow lab-mate in for the stimulating discussions, for the hard work and difficulties we were facing together before deadlines that all turns into happiness, and for all the fun we have had in the last weeks. Also I thank my friends for their motivation and continuous support, for believing in me and always be there.

Last but not the least, I would like to thank my family: my parents and to my brother and sisters, relatives for supporting me spiritually throughout writing this thesis and my life in general.

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Abbreviation	Definition
GIS	Geographic Information System
AHP	Analytic Hierarchy Process
MCA	Multi Criteria Analysis
MCDA	Multi Criteria Decision Analysis
SDSS	Spatial Decision Support System
DSS	Decision Support System

Abstract

Restaurants has become one of the most important facilities that generates a huge amount of revenues in community that helps in economic growth of the country ,it's not just a place for serving food and drinks but it's also one of the important tourism places that visitors could come to. The research aims to find best location for building a restaurant that guarantees its suitability, accessibility, durability, and visibility. GIS which is a powerful tool in spatial analysis and decision making can be utilized for this purpose efficiently and effectively, using weighted site selection analysis in defining the problem, collecting data, ranking criteria according to their weights and re-classifying the criteria using weighted sum equation to obtain the suitability map.

This research took Khartoum locality as study area and "Papa costa" restaurant as an example to find the best location to build a new "papa costa" branch.

The final result visualized the optimal site to build a new "Papa costa" branch in term of compatibility with the study criteria is in the area near Nile Street.

ملخص

أصبحت المطاعم واحدة من أهم المنشآت التي تولد كمية كبيرة من العائدات في المجتمع التي تساعد في النمو الاقتصادي للبلد، إنها ليست مجرد مكان لتقديم الطعام والمشروبات لكنها أيضا واحدة من الأماكن السياحية الهامة التي يمكن أن يأتي إليها الزوار. يهدف البحث للعثور على أفضل مكان لبناء مطعم يضمن ملاءمته وسهولة الوصول إليها ، ووضوح الرؤية. نظم المعلومات الجغرافية التي هي أداة قوية في التحليل المكاني وصنع القرار يمكن استخدامها لهذا الغرض بكفاءة وفعالية، وذلك باستخدام أداه التحليل weighted site selection في تحديد المشكلة، وجمع البيانات، وترتيب المعايير وفقا لأوزانها وإعادة تصنيف-المعايير باستخدام معادلة weighted sum للحصول على خريطة ملاءمة.

تم إتخاذ محلية الخرطوم كمنطقة دراسه البحث وإتخاذ مطعم "بابا كوستا" كمثال لإيجاد أفضل منطقة لبناء فرع جديد لة.

تصور النتيجة النهائية الموقع الأمثل لبناء فرع جديد للمطعم من حيث التوافق مع معايير الدراسة وهي المنطقة بالقرب من شارع النيل.

Chapter 1

Introduction

Introduction

1.1 Overview

Location is often considered the most important factor leading to the success of a private- or public-sector organization. Private-sector organizations can profit from a good location, whether a restaurant or a small coffee shop with a local clientele or a multinational network of factories with distribution centers and a worldwide chain of retail outlets. Location can help keeping fixed and overhead costs low and accessibility high. [1]

Also research on the customer satisfaction has flourished over the past two decades becoming one of the most popular topics in the service marketing. Generally food service companies are using customer satisfaction data to determine the level of service quality in order to increase customer retention.

Restaurant site selection is a complex decision often made without proper planning or sufficient information. It is generally held that the site selection process is more art than science and therefore difficult to quantify. The most important aspect of site selection is to assure that all factors that could possibly have any bearing on the decision are considered carefully.

1.2. The research problem

Bad locations of restaurants have negative effects to provide services to the beneficiary. If the location of a restaurant is far from any populated area (area of demand) the beneficiary may not be able or interested to take the service from the restaurant. That means, the distance from the restaurant and the area of demand should be optimal.

1.3. Rationale of the study

The best location depends on criteria like the optimal distance, the capacity of the facility, population density, optimal cost, visibility, accessibility etc. So the goal of this study is to find the best location or locations to fit one or more facilities, which will make the highest utility value from one criterion or multiple criteria.

1.4. The objectives of the study

- To find the optimal/ best location for restaurants using the GIS ArcGis.

- To evaluate the alternative for the best location.

1.5. The research questions

- How to prepare/process/analyze the city data to find optimal/best restaurant locations using ArcGIS.
- How to find alternatives or best next location for new restaurants.

1.6. The research hypothesis

By the end of this study, a best location and the alternative or best-next location for a new restaurant in Khartoum state should be found, the hypothesis is, that successful restaurant site selections have a significant positive impact on decreasing losses on short term and also long term for business owners.

Chapter 2

Related work and literature review

2.1. Theoretical Frameworks

2.1.1. A Geographic Information System (GIS)

According to Environmental Systems Research Institute (ESRI, 1990), a Geographic Information System (GIS) is "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information." From the perspective of application, GIS is consisted of five key parts: hardware, software, data, methods and people.

The data and information in GIS is geographically referenced (geo-coded). For the GIS methods "A GIS has considerable capabilities for data analysis and scientific modeling, in addition to the usual data input, storage, retrieval, and output functions". [2]

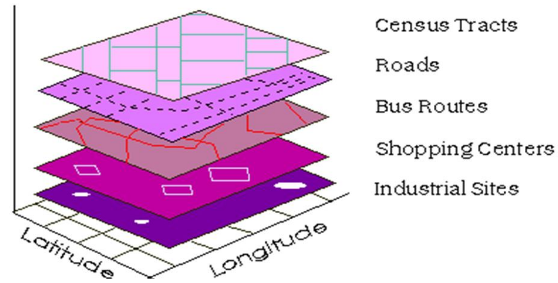


Figure (2.5) GIS: Data layering

2.1.2. GIS Applied on Site Selection

GIS is an innovative integrated technology based on many disciplines such as Computer science, Geography, Cartography, Statistics, Remote Sensing, Land Surveying and Navigation. With a period of nearly 50 years of development, together with the popularization of the Internet, GIS has been widely immersed in the people's daily life like Global Positioning System (GPS) navigation. In the Land Management domain, GIS has been applied efficiently to deal with the geo-spatial data for screening and evaluation, facilitating the optimal site selection. A number of tools are available to determine the optimum site (Witlox, 2005). Traditional methods of GIS site selection are based on the transformation of effective layers into a classified map, such as using a Boolean model or Index Overlay operations. [2]

2.1.3 Overview of Weighted Site Selection and Suitability Analysis

Site selection or suitability analysis is a type of analysis used in GIS to determine the best place or site for something. Potential sites used in suitability analysis can include the location of a new hospital, store or school among many others. When performing site selection analysis users must set various criteria from which the GIS software can rate the best or ideal sites. Site selection analysis can be performed with vector or raster data but one of the most widely used types of site selection, weighted site selection, uses raster data.

Weighted site selection analysis allows users to rank raster cells and assign a relative importance value to each layer (ESRI). The result is a suitability surface which ranks potential sites from 1 to 5. Sites with a value of 1 are least suitable and those with a value of 5 are most suitable. Weighted site selection is an important site selection method because it includes options for viewing next-best sites (those with a value of 4) should the ideal sites not [3].

2.1.3.1 How to Use Weighted Site Selection in GIS

In order to use weighted site selection there is a standard workflow that should be followed. This workflow usually begins with defining a problem or criteria here to find the best site location for a restaurant. The next step is to gather data and create raster surfaces to be used in the analysis. This step is followed by reclassifying the layers, weighting them and then overlaying the output layers with background information such as a map of topography to see the best potential sites.

Reclassification is important in weighted site selection because it is used to simplify the interpretation of raster data by changing a single input value into a new output value (ESRI). It can also be used to group ranges of cell values into a single value. For example you can assign a value of 1 to a set of values that range from 1-50 and 2 to values that range from 51-100. This simplifies weighted site selection because different types of raster data will have different values based on what they show (ESRI). By using reclassification they are all based on the same ranking scheme that can be used to compare and rank the least and most suitable sites.

Weighting layers is another critical step in weighted site selection because it allows the user to place varying levels of importance on different factors such as proximity to a major roads and rivers (ESRI). Weights are usually determined by a panel of experts on the subject being tested and they are based on specific criteria for the analysis. In this study weights have been extracted using the AHP model. [3]

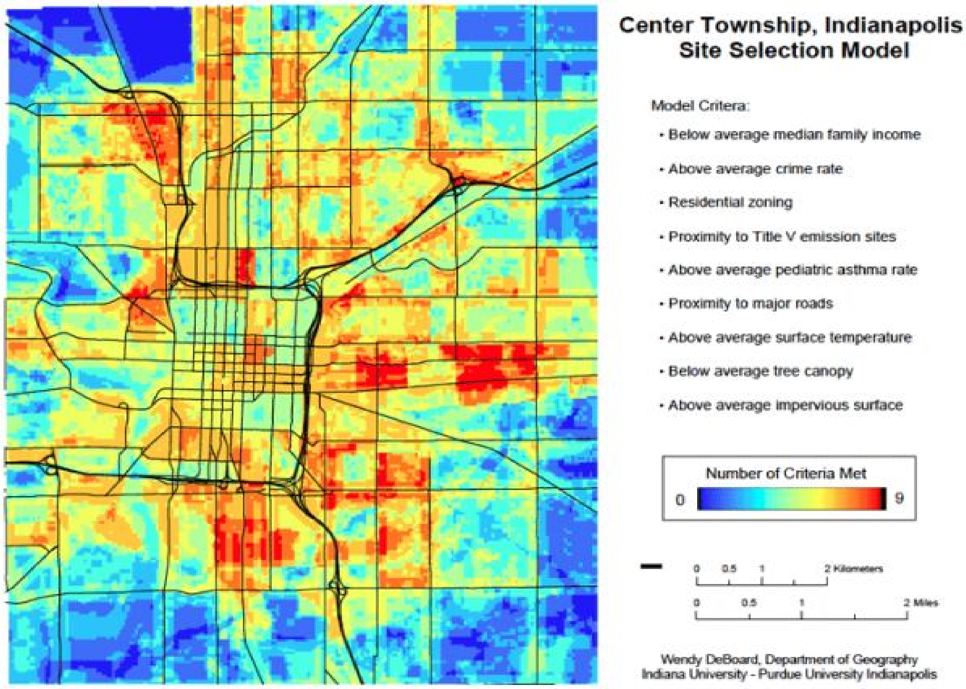


Figure (2.6) Site selection model and suitability analysis

2.1.3.2 Why to use Weighted Site Selection for this Study?

Weighted site selection or suitability analysis is best to use with raster data when a user needs to find a site based on a number of criteria such as the following problems explained by the ESRI Virtual Campus course "Using Raster Data for Site Selection":

- When one needs to find the rankings of suitability for cells in a raster dataset.
- When one needs to find next-best site options in addition to finding an ideal site.
- When data has a distinct boundaries and other levels of certainty.
- When the user determines where something will go based on specified criteria.
- When the user wants to rank different criteria as more or less important in finding an ideal site.[3]

And this is what this study needs in order to make the final decision making.

2.2 Literature Review

In the following some literature review is being made to become familiar with the underlying problem and to find some gaps to be closed by this study.

Case1:

Title: Utilizing GIS-Based Site Selection Analysis for Potential Customer Segmentation and Location Suitability Modeling to Determine a Suitable Location to Establish a Dunn Bros Coffee Franchise in the Twin Cities Metro, Minnesota [4]

Name of researcher: Linder G. Ringo Department of Resource Analysis, Saint Mary's University of Minnesota, Minneapolis MN 55404

Objectives: Determine a Suitable Location to Establish a Dunn Bros Coffee Franchise in the Twin Cities Metro, Minnesota.

Software and Technologies Used:

ESRI‟s ArcGIS 9.3, Spatial Analysis tools, Microsoft Excel, and Notepad. These tools were used for data collection, transformation, manipulation,

Result:

Figure 2.3: Suitable locations (red color) to establish a Dunn Bros Coffee franchise. White areas did not fit in the analysis based on the criteria used to conduct this study.

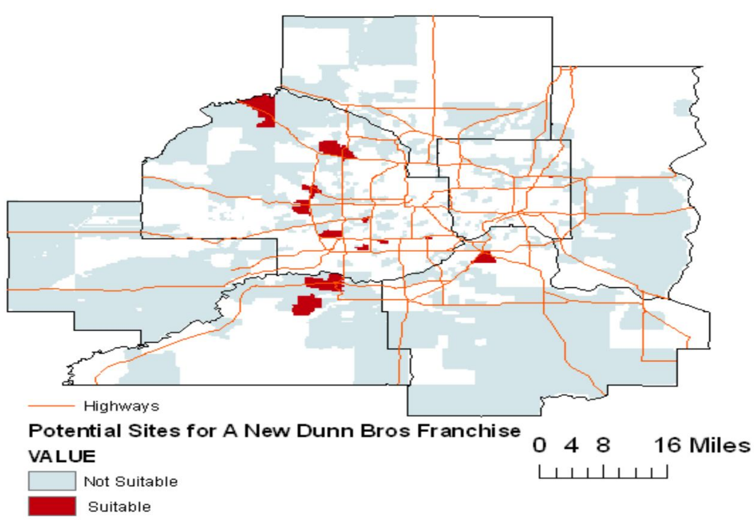


Figure (2.3) Suitability Map for Dunn Bros Coffee Franchise

Conclusions and frameworks

The project was designed to assess Dunn Bros Coffee franchise site locations in reference to Dunn Bros „siting‟ selection criteria based on macro level criteria. The results from the study can be useful to the public, Dunn Bros Coffee"s real estate team, and business entrepreneurs in the area.

The analysis also demonstrated how GIS can be used to provide a spatial depiction of suitable location(s) where an entrepreneur could establish a Dunn Bros Coffee house franchise. Finally, it demonstrates that GIS technology and applications analysis of this project can assist.

Case2:

Title: Multi-criteria GIS-based procedure for coffee shop location decision [5]
Name of researcher: Xiangyi Lin & Yuanyuan Zu

Objectives:

1. Through comparing the three resultant maps; best location map for the AHP model, best location map for the Huff model and best location map for both the AHP and Huff model, and combing this with the actual situation, the best location of a coffee house will be found.

2. To investigate the similarities and differences of the two site selection models, the Huff model and the AHP based model.

3. To summarize the necessary factors that mainly influence coffee shop location.

Software and Technologies Used:

Quantum GIS (Quantum GIS, 2013), ArcGIS (ESRI, 2013a), ERDAS (IINTERGRAPH, 2013) and AHP (Brandt, 2006). Quantum GIS (QGIS) was used for obtaining data from OSM so that the landuse map could be directly exported to ArcGIS.

Results:

The most important result is the combined result in this study. It is based on a MCA model and the Huff model that considered relatively comprehensive factors to be more objective. Large parts of them were consistent, while some discrepancies occurred. Although the Huff result appeared as blocks, the AHP based result was usually located within the blocks highlighted in the Huff result. According to these results, it should be noticed that the aggregated three optimal locations are all situated in (or near) the areas that are easy to access and have constant flow of potential customers passing by, which implies that both traffic patterns and population are very important for the coffee shop site selection.

Conclusions and frameworks

This study is mainly concentrated on using two different models, the Huff model and AHP based MCA model, to select the most feasible areas for coffee shop location. The project did not only compare the two models, the Huff capture was also used as a criterion to join into the AHP analysis to get a combined result. The general result provides a solution if there are few intersection areas between the AHP based result and the Huff result. The procedures can be considered as a reference for coffee shop location selection in other cases.

Case3

***Title**:* Multi-Criteria Suitability Analysis for Domino's Pizza
Over Delhi Using AHP and GIS [6]

Name of researcher: Bakul Budhiraja, Richa Sharma
1 Masters Student, TERI University
2PHD. Scholar, TERI University
Address: 10, Vasant Kunj, Institutional Area, New Delhi, DL 110070[4]

Objectives:

- The increasing popularity of Domino's pizza in urban areas of Delhi is amplifying the demand to open new outlets to cater the need.
- The construction of a new outlet must take these criteria's into consideration – land use pattern, transport convenience, social preferences, youth's food habits etc.

Software Used:

 ArcGIS 10.1

Results:

We get a Site Suitability Map for Domino's Pizza with four regions ranging from Highly Suitable area to Unsuitable area (see fig. 2.4).

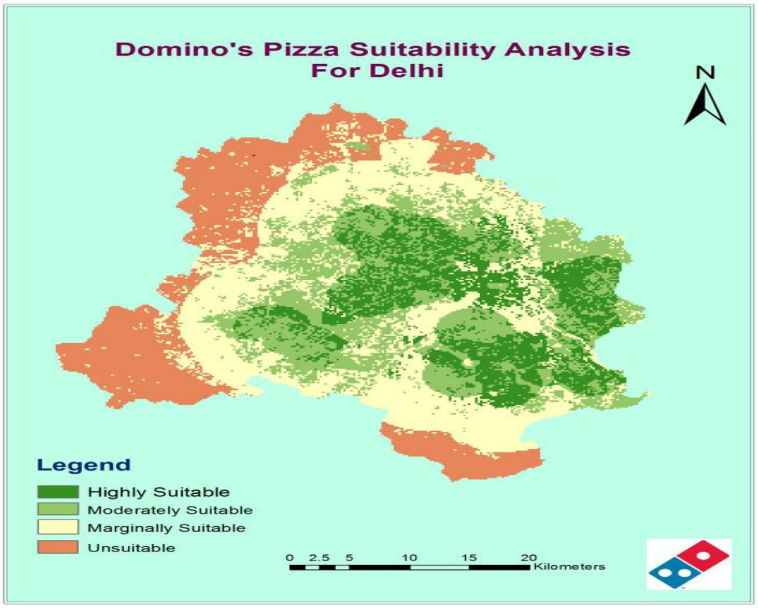


Figure (2.4) Suitability Map for Domino’s Pizza in Delhi

Conclusions and frameworks:

The areas shown in dark green are the most suitable for constructing a new Domino’s Pizza Outlet .These areas are located on settlement class where most of the urban population prevails, have good connectivity through metro network, are closer to malls and campus area where most of the youth population & office goers are found, therefore the demand for new outlets is high in these areas. If the new outlet is located in these highly suitable zones, chances of grossing huge profits is high.

2.3 System Description

2.3.1 Current System

In the early stage, site selection was usually mixed up with large amount of statistics, written narrative, questionnaires as well as some simple geographic methods. Probably the typical geographic approach was using Thiessen polygon diagrams. This is a process to decompose a specific given space in the basis of distances and objects. These objects are usually called sites. The principle of this diagram is to produce regions whose boundaries define the area in which the distance of any location to the given site is not greater than the distance to other sites. It is well-known in computer science and employed in all kinds of fields, such as natural science or even art. In geographic category, the famous climatologist Thiessen (1911) introduced the diagram initially. He evaluated the average precipitation cover grand areas through allocating proximity polygons to sites (see figure 2.5) [7].

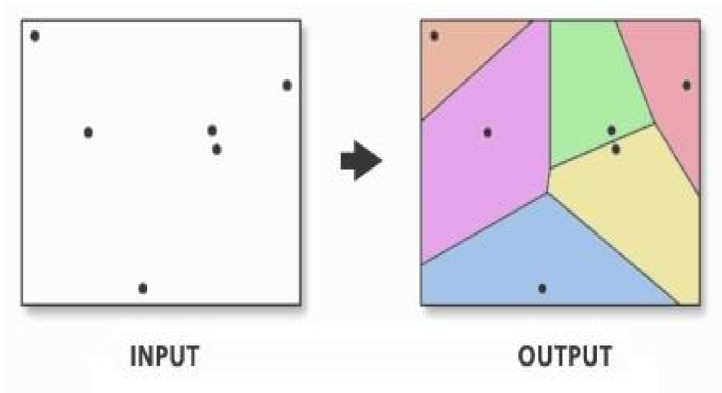


Figure (2.5) Thiessen diagram

2.3.2 Current System Problems

1. Depends on distances, does not cover most of the main criteria, that should be taking into account when building a new restaurant.
2. Does not rank each criterion according to their importance.

2.3.3 Proposed Solution

Suitability analysis using MCA and AHP model.

2.3.4 Proposed System Description

In this study we are going to use site selection or suitability analysis which is a type of analysis used in GIS to determine the best place or site for something. Potential sites used in suitability analysis can include the location of a new hospital, store or school among many others. When performing site selection analysis users must set various criteria from which the GIS software can rate the best or ideal sites. Site selection analysis can be performed with vector or raster data but one of the most widely used types of site selection, weighted site selection, uses raster data.

Weighted site selection analysis allows users to rank raster cells and assign a relative importance value to each layer. The result is a suitability surface which ranks potential sites from 1 to 5. Sites with a value of 1 are least suitable and those with a value of 5 are most suitable. Weighted site selection is an important site selection method because it includes options for viewing next-best sites (those with a value of 4) should the ideal sites not. [8]

2.3.5 Proposed System Problems

1. Spatial decision problems typically involve a large set of feasible alternatives & multiple evaluation criteria o most of the time, these are conflicting.

2. Alternatives & criteria are often evaluated by a number of individuals (decision-makers, managers, stakeholders, interest groups). Most of the time, they also have conflicting ideas, preferences, objectives, etc.

3. Many spatial decision problems give rise to the GIS-based MCDA to aid in the decision making process [9].

2.3.6 Structure of the Study

This thesis unfolds in the following fashion: chapter 1 describes objectives, problems, hypotheses of the study. Chapter 2 represents overview, literature studies and system description. Chapter 3 presents the execution flow chart of this study, AHP and Weighted Overlay approach. Chapter 4 provides the implementation. Section 5 presents final results and screen shots. Chapter 6 presents conclusions. Finally chapter 7 provides us with references of this study.

2.3.7. Frame Work for Spatial Decision Making

Decision making is a sequence of activities starting with decision problem recognition and ending with a recommendation, and eventually with a final choice of alternative. As the storage and processing capacity of human memory is limited, humans develop simplifying cognitive shortcuts or processing rules to solve complex problem. There are a number of alternative ways to organize the sequence of activities in the decision-making process - the quality of the decision making arguably depends on the sequence on which the activities are undertaken.

Computers have been used to develop decision-support-systems (DSS), GIS has been referred to as a specific kind of decision-support-system dealing with problems which involve a high degree of spatiality and which can provide a framework for the development of spatial decision support system (SDSS), particularly when coupled either loosely or tightly with other model software.

Spatial decision support systems and decision support systems share the same characteristics but the former (SDSS) presents in fact an extension of (DSS) (see figure 2.6).

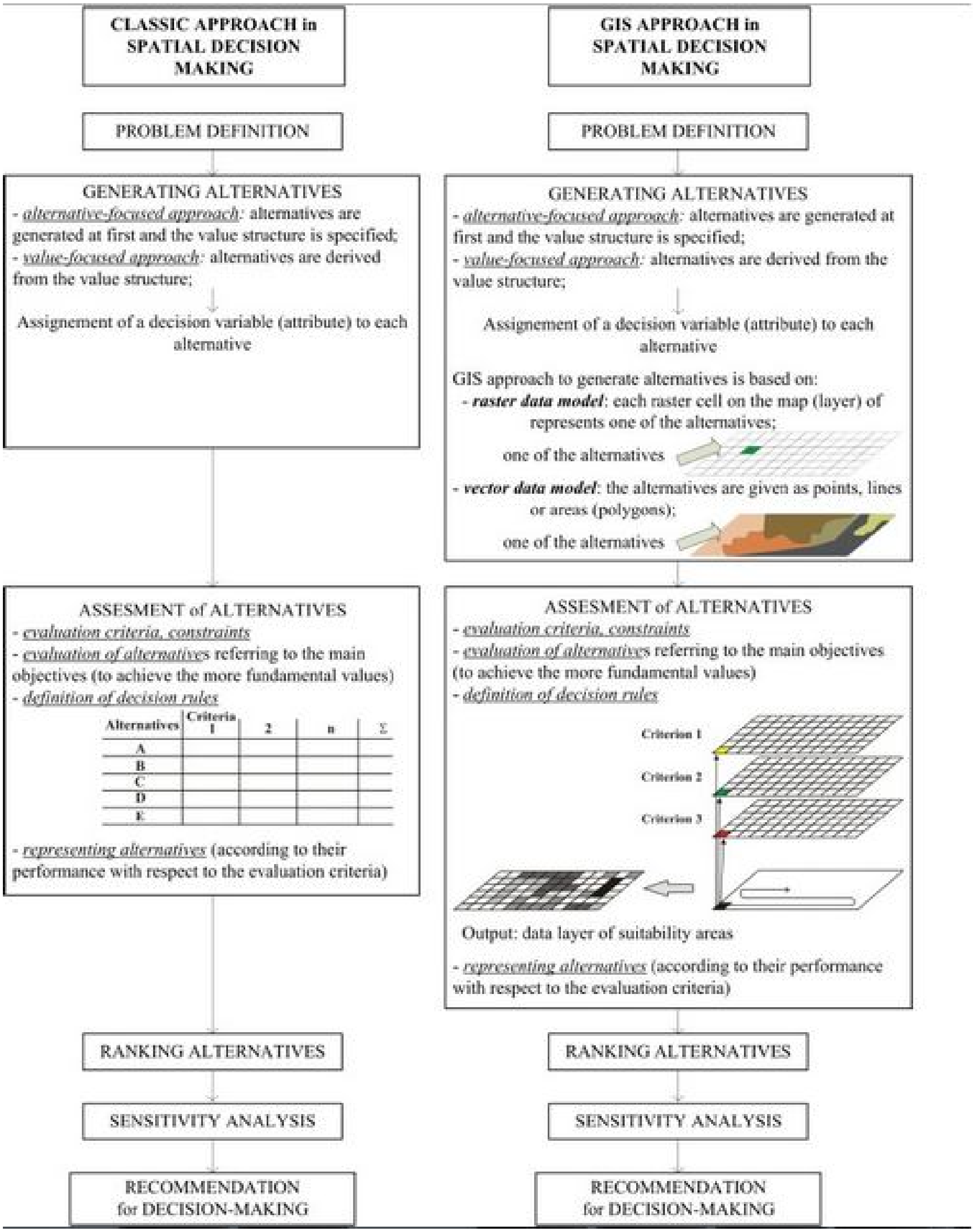


Figure (2.6) DSS vs. SDSS

One of the most important rules governing the use of GIS for SDSS is that GIS themselves do not make decisions at all - people do. In SDSS the emphases is on the use of spatial data and in GIS it is on supporting decision makers in the decision-making process to choose the alternative (decision) which is the best solution to the problem that needs to be solved. [10]

Chapter 3

Methodology and research planning

3.1 GIS applied on site selection

3.2 Research community

3.3 Society and sample of the study

3.4 Methodology and research planning

3.5 Selected methodology and techniques

Overview

This chapter will present research community, society, sample of the study, methodology and research planning.

3.1 GIS Applied on Site Selection

According to the Environmental Systems Research Institute (ESRI, 1990), a Geographic Information System (GIS) is "an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information." From the perspective of application, GIS is consisting of five key parts: hardware, software, data, methods and people. The data and information in GIS is geographically referenced (geo-coded). For the GIS methods holds "A GIS has considerable capabilities for data analysis and scientific modeling, in addition to the usual data input, storage, retrieval, and output functions".

GIS is an innovative integrated technology based on many disciplines such as Computer Science, Geography, Cartography, Statistics, Remote Sensing, Land Surveying and Navigation. With a period of nearly 50 years of development, together with the popularization of the Internet, GIS has been widely immersed in the people's daily life like Global Positioning System (GPS) navigation. In the Land Management domain, GIS has been applied efficiently to deal with the geo-spatial data for screening and evaluation, facilitating the optimal site selection. A number of tools are available to determine the optimum site.Traditional methods of GIS site selection are based on the transformation of effective layers into a classified map, such as using a Boolean model [13].

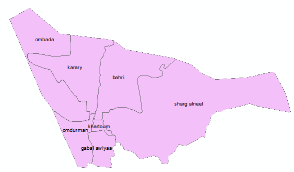
3.2 Research community

This research is for business owners, who are interested in building new restaurants in Khartoum.

3.3 Society and Sample of Study

Khartoum is the capital and second largest city of Sudan and Khartoum state. It is located at the confluence of the White Nile, flowing north from Lake Victoria, and the Blue Nile, flowing west from Ethiopia .The location where the two Niles meet is known as "al-Mogran"المقرن, meaning the confluence. The main Nile continues to flow north towards Egypt and the Mediterranean Sea.

Divided by the Niles, Khartoum is a tri-partite



Khartoum State

metropolis with an estimated overall population of over five million people, consisting of Khartoum proper, and linked by bridges to Khartoum North (الخرطوم بحري al-Kharṭūm Baḥrī) and Omdurman (أم درمان Umm Durmān) to the west.[14]

Figure (3.1) Location map of Khartoum state

3.4 Methodology and Research Planning

3.4.1 Conventional Way of Site Selection

Site selection plays a vital role for both social and economic activities, from the habitat choice of our human ancient ancestors to all kinds of present commercial site selection. Everybody knows that inappropriate site selection leads to heavy losses, but may not very sure what is the exact importance. Take the business operations as an example, site selection is the first key factor and directly related to the customer groups, capital investment and recovery, and development strategy. Therefore, making good preparations and analysis on the parameters of the site selection is absolutely necessary. [7]

3.4.2 Data Source

1. *GADM is a geographic database of global administrative areas (boundaries).*
2. *Surveying.*
3. *Internet.*

3.4.3 Geoprocessing

Geoprocessing is one of the most powerful components of a geographic information system (GIS). Geoprocessing allows you to define, manage, and analyze the information used to form decisions [17].

3.4.4 Existing Techniques Used in Site Selection

The following GIS software can be used for site selection applications:

- ERDAS
- QGIS.
- ArcGIS

3.4.5 Existing GIS Approaches Used in Site Selection

The GIS approaches used in the site selection usually are network analysis, spatial analysis, proximity analysis, MCDA with AHP, FAHP or ROM, etc.

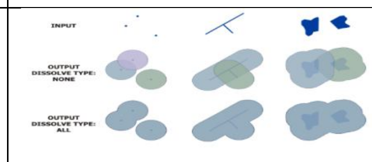
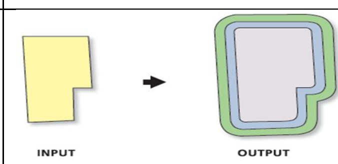
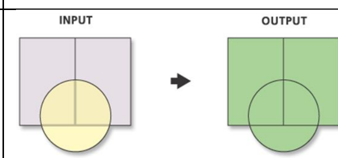
3.5 Selected methodology and techniques

For this study, GIS-based MCDA with AHP using ArcGIS have been chosen.

3.5.1 ArcGIS

Esri's **ArcGIS** is a Geographic Information System (GIS) for working with maps and geographic information. It is used for: creating and using maps; compiling geographic data; analyzing mapped information; sharing and discovering geographic information; using maps and geographic information in a range of applications; and managing geographic information in a database [17].

Table (3.1) Basis ArcGIS tools that have been used in the study

Tool	Description	Illustration
Buffer	It creates buffer polygons around input feature to specific distance.	
Multiple ring buffer	It create multiple buffers at specified distances around the input	
Union	Calculate the geometric union of any number of feature classes and feature layers	
Feature to raster	Convert feature to raster date set	-
Reclassify	Reclassifies or changes the values in a raster	-
Is Null	Determine which values from the input raster are NoData on a cell-by-cell basis, returns a value of 1 if the input value is NoData and 0 for cell that are not	-

3.5.2 Model-Builder:

Model-Builder is a visual programming language for building geoprocessing workflows.

The Model-Builder in ArcGIS allows you to do the following:

- Build a model by adding geoprocessing tools, map layers, datasets, and other data types, and connecting them to a process.
- Iteratively process every feature class, raster files, or table in a workspace.
- Visualize your workflow sequence as an easy to understand diagram.
- Run a model step-by-step, up to a selected step, or run the entire model.
- Make your model into a geoprocessing tools that can be shared with others or can be used in python scripting and other modules [16].

This study used Model-Builder for visualizing and illustrating the workflow of suitability analysis steps. It does not use it for building the suitability modeling.

3.6 Basic Principles of GIS-based MCDA:

- **MCDA:**
  Provides a rich collection of techniques & procedures for structuring decision Problems, designing, evaluating and prioritizing alternative decisions.
- **GIS-MCDA:**
  Can be thought of as a process that transforms & combines geographical data value judgments (the decision-maker’s preferences) to obtain information for decision making.
- **Decision:**
  Is a choice between alternatives, i.e. best land use among different land use alternatives?
- **Criteria:**
  Are a set of guidelines or requirements used as basis for a decision.
  There are two types: factors & constraints
  - A factor is a criterion that enhances or detracts from the suitability of a specific alternative for the activity under consideration, i.e. distance to road (near = most suitable; far = least suitable)
  - A constraint serves to limit the alternatives under consideration. This may overlay an element or feature that represents limitations or restrictions; or an area that is not preferred in any way or considered unsuitable. I.e. protected area, water body, etc. (usually represented by a Boolean mask).

- **Suitability**

Is the characteristic of possessing the preferred attributes or requirements for a specific purpose?

- **Suitability analysis**

  Is a GIS-based process used to determine the appropriateness of a given area (land resource) for a specific use, i.e. agriculture, forestry, business, urban development, livelihood projects, etc.

3.6.1 Methods of Multi-Criteria Analysis (MCA)

MCA steps can be summarized as follow:

1. **Set the goal defining the problem.**

   As a general rule, a goal must be: **S M A R T**[1]

   S – specific

   M – measurable

   A – attainable

   R – relevant

   T – time-bound

2. **Determine the criteria (factors/constraints)**

   In general we have to consider, how much details are needed in the analysis. This affects the set of criteria to be used.

   I.e. main roads only vs. including minor roads; no. of houses vs. no. of residents; etc.

   - Criteria should be measurable.
   - If not determinable, use proxies o i.e. slope stability can be represented by slope gradient.

3. **Standardize the Factors/Criterion Scores:**

   Set the suitability values of the factors to a common scale to make comparisons.

Table (3.2) Factor/criterion suitability scores

Factor	**Suitability**

5	**Most suitable**
4	**Next-most suitable**
3	**Suitable**
2	**Least suitable**
1	**Not suitable**

4. **Determine the weight of each factor:**

   There are several methods:

   - Ranking:

     i.e. 3 factors: rank the factors with 1, 2, & 3, where 1 is the least important while 3 is the most important (this is adopted in the study).

   - Rating: i.e. 3 factors: rate the factors using percentile – Factor 1 with the lowest percentage as the least important & Factor 3 with the highest percentage as the most important.

   - Rankings & ratings are usually converted to numerical weights on a scale 0 to 1 with overall summation of 1 (normalization), i.e. Factor 1 = 0.17; Factor 2 = 0.33; & Factor 3 = 0.50.

5. Aggregate the Criteria

Weighted Linear Combination (WLC) is the most commonly used decision rule based on

$$S=\sum_{i=1}^{n} wiCi \prod_{i=1}^{m} ri \qquad [8]$$

Where:

S – is the composite suitability score xi – factor scores (cells)

wi – weights assigned to each factor

cj – constraints (or Boolean factors)

∑ -- sum of weighted factors

∏ -- product of constraints (1-suitable, 0-unsuitable). [9]

3.6.2 Analytical Hierarchy Process (AHP)

AHP, which was proposed by Saaty (1980), is a structured technique for decision making based on a hierarchical framework constructed through mathematical pairwise comparisons. The weights for the decision making criteria are derived from the pairwise comparisons of the relative importance between each two criteria (the sum of the weights equals to 1). Saaty and Vargas (1991) portrayed a scare for the pairwise comparisons, where the judgments are represented by a degree of importance (Table 1). The reciprocals of the numbers are adopted to represent the inverse relationship (Mohammad et al., 2009) [15].

Table (3.3) Intensity of criteria importance

Intensity of importance	Description
1	Equal importance
2	Moderate importance
3	Strong or essential importance
4	Very strong or demonstrated importance
5	Extreme importance

It is necessary to verify the consistency after the gaining of weight values (Chen et al., 2010). The consistency index (CI) and consistency ratio (CR) are depicted as Equations (1) and (2) below:

$$CI = (\lambda - n) / (n - 1) \quad (1)$$

where n = the number of the criterion,

λ= Lambda λ is the average of consistencies

Consistency = {Ws}. 1/ {W},

{Ws} = [C] {W}

$$CR = CI/RI \quad (2)$$

Where RI = a constant corresponding to the mean random consistency index value based on *n*.

The AHP procedure generally consists of six steps:

1) As for the initial unstructured problem, define it and make the aims clearly as well as be sure what results are expected to get.

2) Analyze the complicated problem, set the elements influenced into specific criteria.

3) Apply pairwise comparisons among these criteria to set up the comparison matrices.

4) Adopt some methods such as eigenvalue method to estimate these criteria's relative weights.

5) Check the consistency ratio of the matrices to make sure it is ok for the weight settings

6) Determine the most appropriate weight settings and get an overall rating for these criteria. [13]

Figure 6 gives an overview of the GIS-based MCA model.

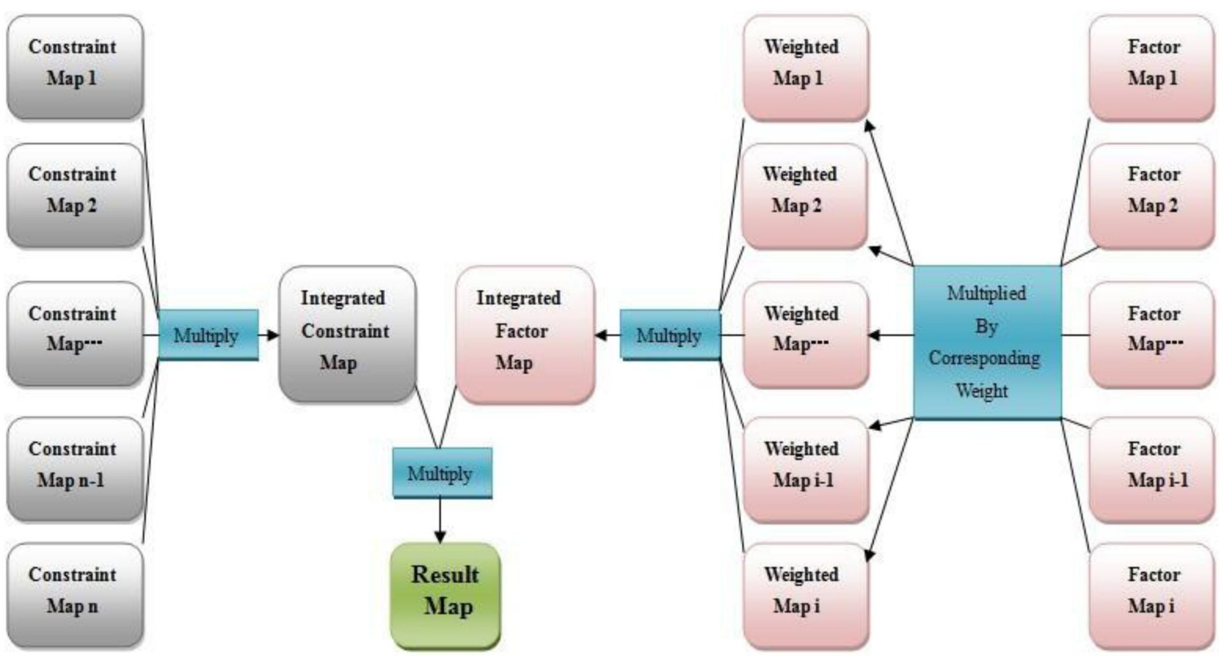


Figure (3.2) GIS-based MCA model

Chapter 4

System analysis and design

4.1 Data preprocessing

4.2 System requirement

4.3 System analysis and design

Overview

This chapter contains functional, non-functional and technical requirements. Also it explains system analysis and design.

4.1 Data preprocessing

All data of this study are on shape file format, most of them are with undefined spatial referencing such as roads, land-use, rivers, and hospitals, but set to (GCS_WGS_1984) Datum of (D_WGS_1984) using the projection and transformation tool in ArcMap. All the other data were in (WGS_1984_World_Mercator, WKID: 3395 Authority: EPSG) coordinate system and projected in (GCS_WGS_1984) Datum of (D_WGS_1984) using the projecting tool in ArcMap.

Several layers have to be preprocessed. Some layers have to be digitized as polygons to get new maps. Some other layers need to be buffered by using the Analysis tool in ArcMap. After being overlaid, the conversion from shapefile to raster format could be accomplished, making it easier to be reclassified in the further data processing.

4.2 System Requirements

4.2.1 Technical Requirements

In order to do the data processing, the following software tools are used:

- ArcGIS 10.3(ArcMap).
- Spatial analyst (Activated).

4.2.2 Factor/Constraint Criteria and Functional Requirements

1. Factor criteria that determine suitability of a new restaurant are:

1. **Distance from main roads**: Theoretically, a restaurant should be located near the roads, especially the main roads. Main roads here in Sudan are primary and secondary roads, in addition we have rails. The overall goal is ”the nearer the better”. However, the noise from motor vehicles passing by

influences the customers in the restaurant. Therefore a quiet distance of 300 meters is set, outside the buffer zone.

2. **Distance from Rails**: In case the new restaurant is located close to rails (Nile river), at least 100 meters distance along the river should be used. Outside the buffer zone, the nearer the better for a good view.
3. **Population density**: A restaurant should be located in a populated area; more population means more visitors.
4. **Land-use**: A restaurant should be located near residential areas, colleges, universities, entertainment places, etc. but far away from fuel or industrial places.
5. **Distance from transport points**: A restaurant should be near a transport point so it could be easy for visitors to reach it, also here holds true: the nearer the better. However, the noise from a transportation point influences the customers in the restaurant. Therefore a quiet distance of 100 meters buffer is set.
6. **Distance from hospitals**: A restaurant must be far from hospitals because this might be (theoretically) an infectious area. In order to guarantee healthiness of the restaurant and its customers we say here: “The further the better”.

2. Constraint criteria:

1. **Hospitals**: Hospitals are a source of infection. Therefore, to protect the general public a restaurant should not be built near hospitals.

2. **Roads**: A restaurant should not be located inside a street.

3. **Water area**: A restaurant should not be located inside water areas (exception: islands)

In table (4.1) the constraints are summarized.

Table (4.1) Constraint criteria settings

Constraint	Setting(0= forbiddance; 1=allowance)

Hospitals	Buffer of 500 meter is set(inside=0, outside=1)
Roads	Buffer of 5 meter is set(inside=0, outside=1)
Water areas	Buffer of 10 meter is set(inside=0, outside=1)

4.2.3 Non-functional Requirements

1- Suitability: Restaurant location must be suitable.
2- Accessibility: Restaurant must be accessible for potential customers.
3- Durability: Best site selection must overcome long term loses.
4- Visibility: Restaurant must be visible.

4.3 System Analysis and Design

4.3.1 ArcMap Tools Applied

The following points explain how ArcMap tools are applied on each criterion:

1. Factor criteria model:

- **Main road:**

1. Extract all main roads from Khartoum road network using "select" by attribute function.
2. Appling a multiple ring buffer tool on the extracted roads with (500, 1000, 1500, 2000, 7000) meter distances.
3. Union the road buffers with Khartoum locality layer, this will deliver the full shape of Khartoum state, using the union tool.
4. Convert the resulted union layer to raster using Feature-to-Raster tool according to buffer distances.
5. Classify the resulted raster from step 4 onto 5 classes, where 5 has the minimum value (the nearest the better).

- **Hospitals**:

1. Applying Euclidian distance tool on hospital points.

2. Reclassify the output from the Euclidian distance onto 5 classes, where 5 has the maximum value (the further the better).

- **Rail**:

1. Applying multiple ring buffer on the rail layer with (500, 1000, 1500, 2000, 3000) meter distances.
2. Union the rail buffers with Khartoum locality.
3. Convert to raster.
4. Reclassify onto 5 classes, where 5 has a minimum value.

- **Transport point:**

1. Applying Multiple ring buffers on hospital points with (500, 1000. 1500, 200, 300) meter distances.
2. Union hospital buffers with Khartoum locality.
3. Convert the resulting layer into raster using feature to raster tool.
4. Classify the resulted raster into 5 classes where 5 has a minimum value.

- **Population**:

This layer has been obtained by rasterizing Khartoum locality shape file by total-population.

1. Reclassify the population raster into 5 classes, where 5 has the biggest density of population.

- **Land-use:**

1. Union land-use with Khartoum locality.
2. Convert the resulted layer to raster by land type.
3. Classify the resulted raster into 5 classes, where 5 of type (residential, university, college) 4 of type forest, 3 of type allotments, 2 orchard, and 1 is industrial and fuel.

2. Constraint criteria modeling:

- Hospitals:

1. Buffering hospital points with 1000 meter using the buffer tool.
2. Apply “Is Null” tool to set 0 for restriction area, and 1 for NoData area.

- Roads network:

1. Buffering road networks with 500 meter using the buffer tool.
2. Apply “Is Null” tool to set 0 for restriction area, and 1 for NoData area.

- Water ways:

1. Buffering water ways with 100 meter using buffer tool.
2. Apply Is Null tool to set 0 for restriction area, 1 for NoData area.

4.3.2 Model-Builder Workflow

The Model-Builder explains all the previous steps in diagrams - it contains 3 parameters:

1. Input layer.
2. Tool function process.
3. Output layer.

The Model-Builder is applied on constraint criteria:

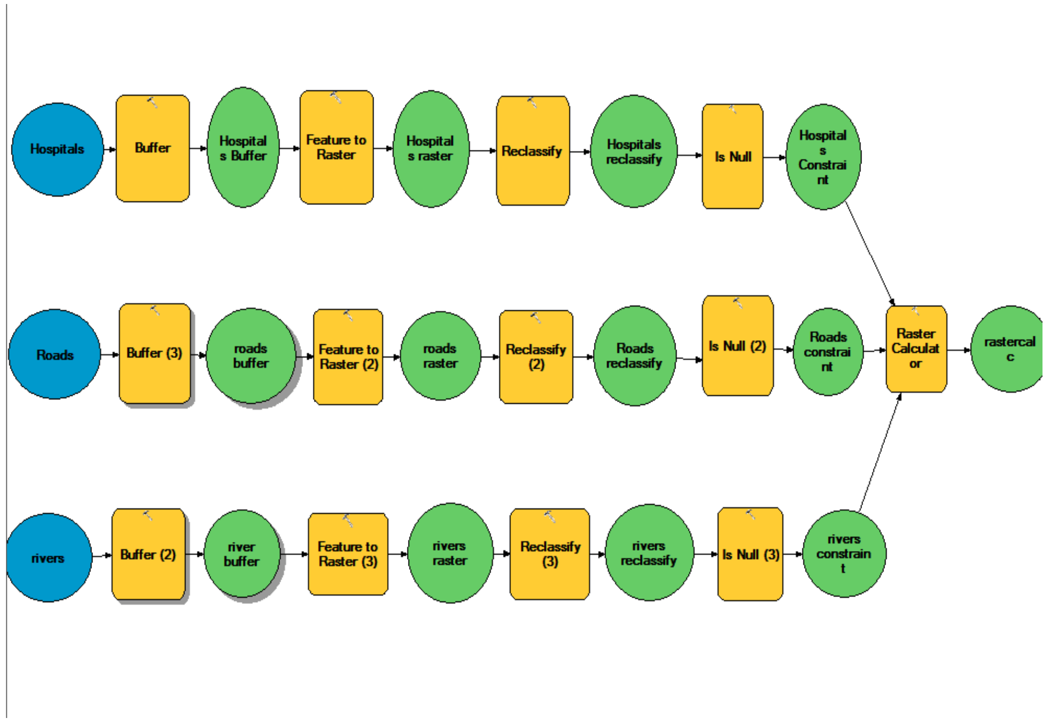


Figure (4.1) Constraint criteria diagram

The Model-Builder applied on factor criteria:

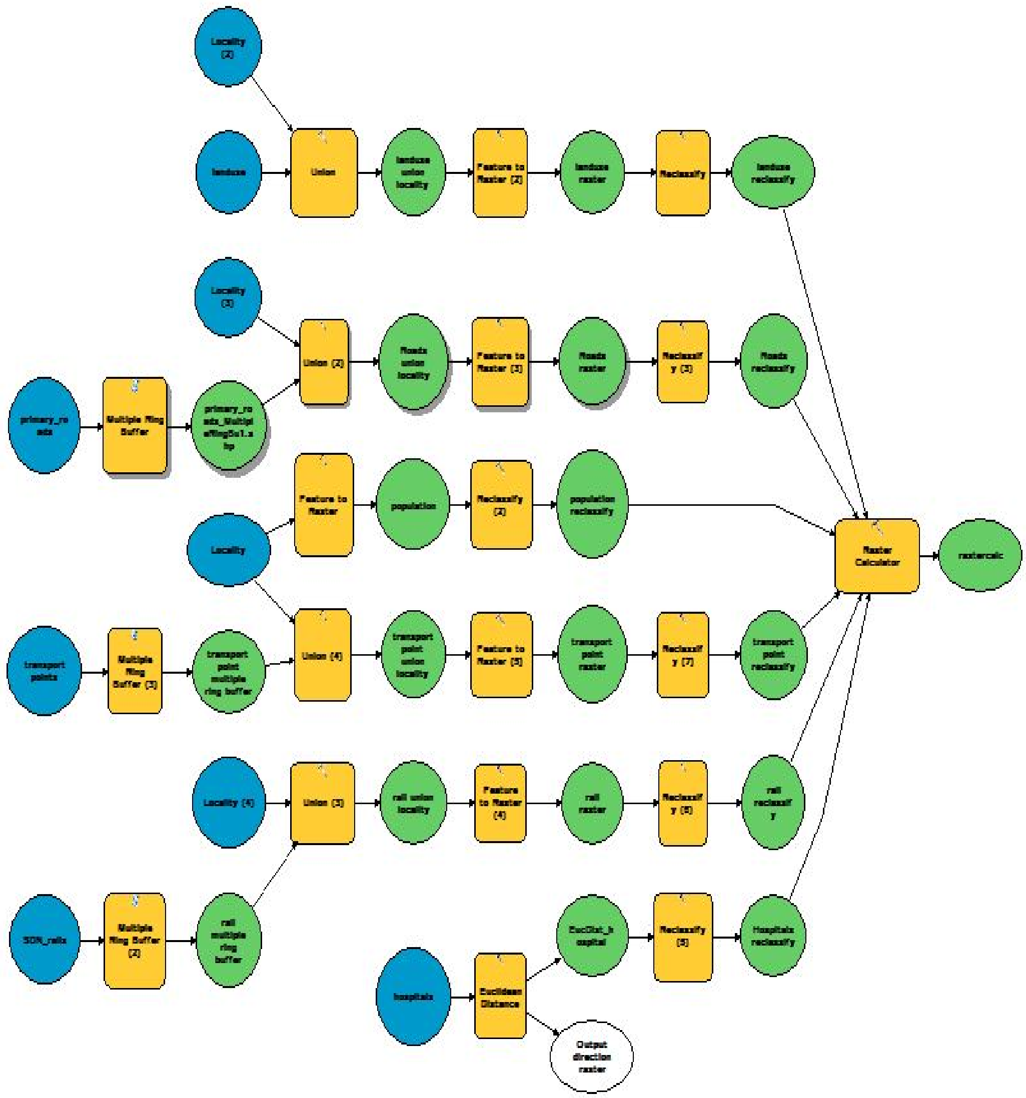


Figure (4.2) Factor criteria diagram

4.3.3 Pairwise Comparison and AHP:

In the following the steps of pairwise comparison and AHP are given in detail:

1. Extract the pairwise comparison of each criterion using pairwise comparisons table described in the previous chapter.

Table (4.2) Criteria comparison matrix[c]

	Land-use	Transport-point	primary roads	Population	rail	hospitals
Land-use	1	0.5	0.333333333	0.25	2	3
Transport-point	2	1	3	3	4	5
primary roads distances	3	0.333333333	1	3	4	5
Population	4	0.333333333	0.333333333	1	2	3
rail	0.5	0.25	0.25	0.5	1	4
hospitals	0.333333333	0.2	0.2	0.333333333	0.25	1
sum columns	**10.83333333**	**2.616666667**	**5.116666667**	**8.083333333**	**13.25**	**21**

2. Normalizing the matrix means to divide each element in every column by the sum of that column (Note: The sum of normalized criteria comparison columns should be 1).

Table (4.3) Normalized criteria comparison matrix[c]

	Land-use	Transport-point	primary roads distances	Population	rail	hospitals
Land-use	0.09230769	0.1910828	0.06514658	0.030927835	0.1509434	0.142857143
Transport-point	0.184615385	0.38216561	0.586319218	0.371134021	0.3018868	0.238095238
primary roads distances	0.276923077	0.12738854	0.195439739	0.371134021	0.3018868	0.238095238

Population	0.36923077	0.12738854	0.06514658	0.12371134	0.1509434	0.142857143
rail	0.046153845	0.0955414	0.048859935	0.06185567	0.0754717	0.19047619
hospitals	0.03076923	0.07643312	0.039087948	0.041237113	0.0188679	0.047619048
sum columns	1	1	1	1	1	1

3. Average each row in the normalized matrix, this average is called the Criteria weights {W}

Table (4.4) Criteria weights

Criteria	Weight {W}
Land-use	0.112210908
Hospitals	0.344036043
Main Roads	0.251811234
Population	0.163212961
Rail	0.086393123
Transport points	0.042335731

4. Checking for consistency: The procedure in checking consistency is:

4.1 Determine a weighted sum vector, {Ws}

Table (4.5) Weighted sum {Ws}

Criteria	Weighted Sum {Ws}
Land-use	0.708762687
Hospitals	2.370781591
primary roads distances	1.750012669
Population	1.110465792
Rail	0.542409801
Transport points	0.274911423

4.2 Calculate the consistency vector from the {Ws} matrix to get lambda:

Table (4.5) Consistency vector

Weight sum	**Consistency vector**
0.92918	6.31634392
0.931706	6.891084925
1.965187	6.949700548
0.850603	6.80378438
2.18505	6.278390902
0.298619	6.493602867
Sum of consistency	**39.73290754**

4.3 Calculate lambda: Average of the consistency vector matrix.

λ= 6.622151257

4.4 Determine the consistency index and random index:

CI= 0.12

RI for n=6 is 1.25 according to Saaty's random index.

After calculating both CI and RI, the final step is to run the consistency ratio equation to check, whether the criteria comparison matrix is consistent or not. If CR <0.10 then it is consistent - if CR>=0.10 the c matrix is not consistent, what means we should revise the pairwise comparison again.

In this case we have to carry out

4.5 Calculate the consistency ratio to check, whether the criteria comparison matrix is consistent or not:

If CR <0.10 then its consistent - if CR>=0.10 the c matrix is not consistent and we should revise the pairwise comparison again.

CR= CI/RI

CR=0.1

So the criteria comparison matrix[c] is consistent and the weights are ready to be applied on the Weighted Linear Combination model.

5. Aggregating the criteria using the Weighted Linear Combination (WLC):

A **weighted linear combination** is an analytical method that can be used when dealing with multi-attribute decision making (MADM) or when more than one attribute must be taken into consideration. Every attribute that is considered is called a criterion. Each criterion is assigned a weight based on its importance. The results are multi-attribute spatial features with final scores. The higher the score, the more suitable the area. A land suitability analysis is an example of a method using a weighted linear combination.

The WCL formula for suitability analysis is given as follows:

$$S=\sum_{i=1}^{n} wiCi \prod_{i=1}^{m} ri \qquad [8]$$

- **Applying restrictions using raster calculator:**

r = (road_restriction)*(hospitals_restriction)*(water-was_restriction)

- **Applying suitability map using raster calculator:**

S= (Roads_reclassify * 0.258504) + (hospitals_reclassify* 0.13671)+ (rail_reclassify * 0.313606) + (land-use_reclassify * 0.129502) + (pop_reclassify *0.115879) + (transport_reclassify* 0.045798)* r

Chapter 5

5.1 Simulation and result

5.2 Screenshots

5.1 Results

The results from the study provide economic insights and opportunities for growth to the community, where a potential franchise could be located. In the long run the franchise could create jobs, revenue, taxes.

5.1.1 Study area:

Figure (5-1) shows a present scenario of Khartoum Locality (Study Area). It contains five layers of existing restaurant, main roads rails, existing hospitals and transport points these layers are representing the important data for this research

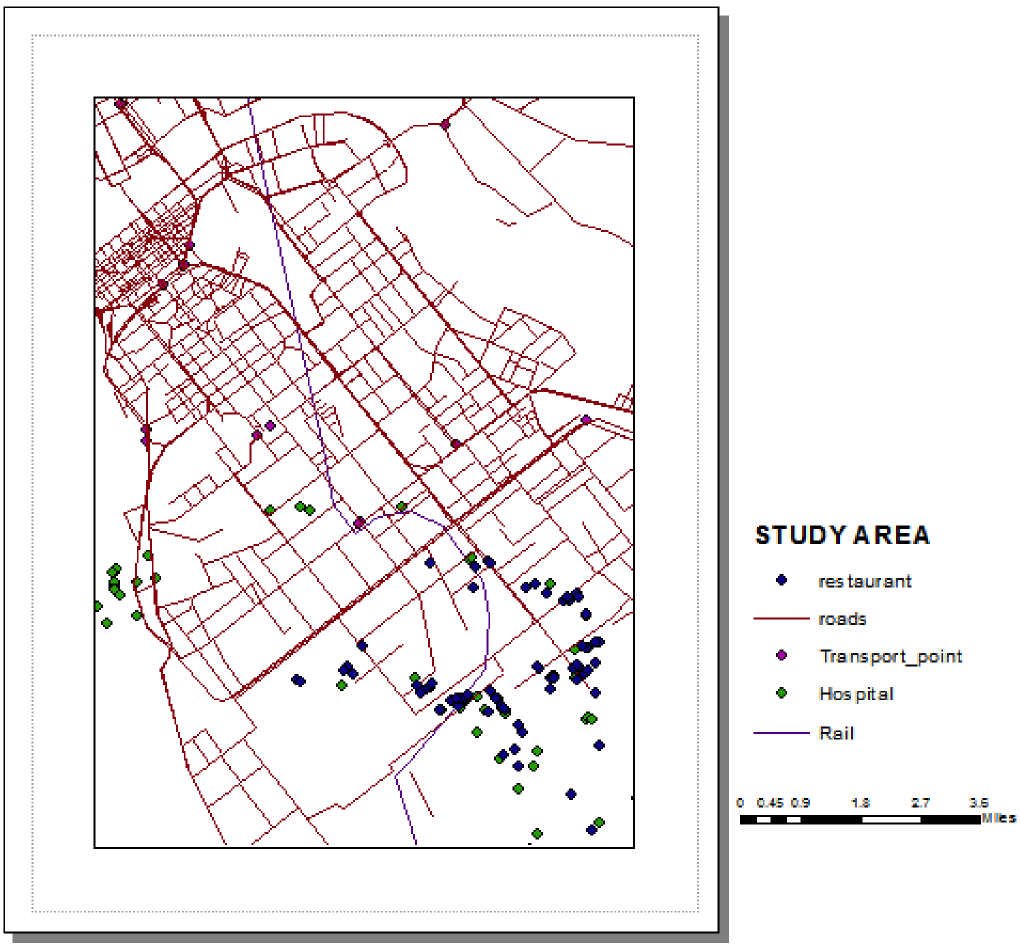


Fig (5.1) study area

5.1.2 Suitability map

Suitability map for building a new restaurant in Khartoum state. It has been obtained after applying the weighted linear combination method, the suitability of this result ranges from red to green from (5 to 1) value. Red or 5 is the most suitable. The map's color ranges from red to lowering green or 1, which is not suitable at all.

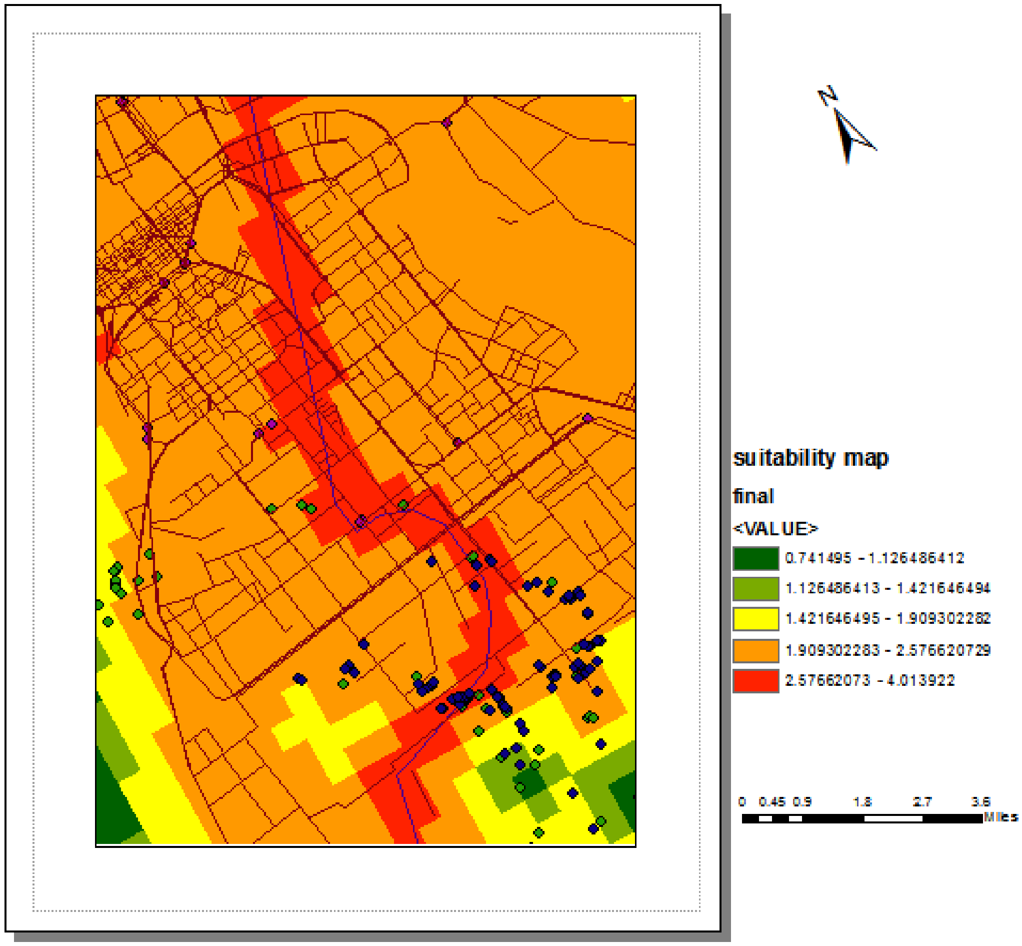


Fig (5.2) suitability model

5.1.3 Optimal locations

After performing a multi-criteria analysis and using the conditional tool (con) thirty tow optimal sites for location a new restaurant were identified in the extension of the study.

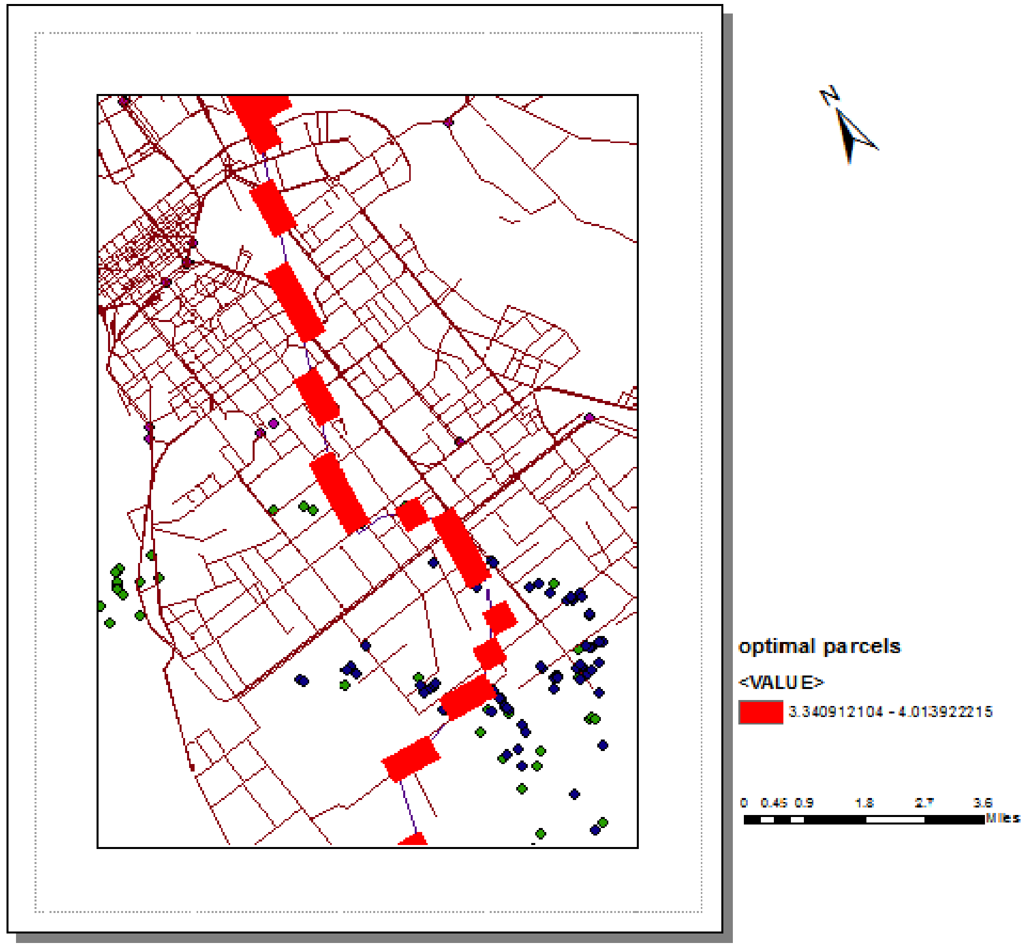


Fig (5.3) optimal locations

Papa costa restaurant has been taken as example to identify optimal site to build a new restaurant, it should be far from the existing one near main road, compatible with the chosen criteria, the optimal among those suitable site is the one near Nile Street.

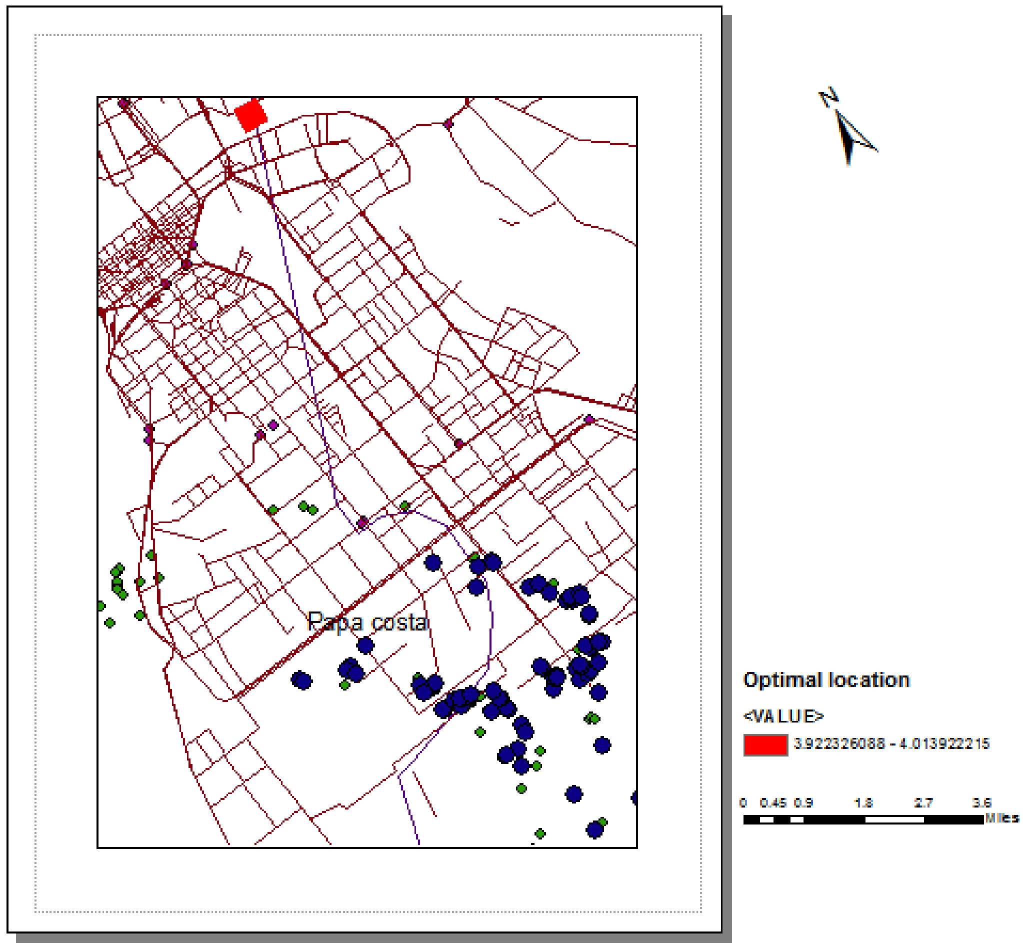


Fig (5.4) optimal location to build a new papa costa restaurant

Chapter 6

6.1 conclusion and outlooks

6.2 limitation of the study

6.3 Recommendation

6.1 Conclusions and Outlook

The results of the study demonstrate the power of GIS in solving complex problems, when used in finding the best location for new restaurants. This task has been achieved successfully by considering the customer as a center of activity, then the facilities offering money and other services, as this the most important means of customer services and ultimately for the benefit of a restaurant.

Restaurant location modeling can eliminate guess work and provides insights about a business location and its future to decide about the best location when needs to build new restaurant. We have demonstrated by simulations that we can predict the potential areas, which means that we can take a decision before building the restaurant.

6.2 Limitations of the Study

- The limitations of this study deal primarily with the lack of data, sensitivity, collection, and formulation of the data.
- Factor criteria priorities in decision-making processes depends on people/business-owners, which may lead to uncertainty.

6.3 Recommendation

- If there are so many criteria to be considered, GIS-based MCA can be applied together with necessity tests and sensitivity tests to make the decision makers aware of, which criteria are really necessary and how the results are sensitive to the weights change. Hence, it can optimize the criteria combination, modifying the analytical structure and reduce the deviation, making the results stronger and more convincing.

Chapter 7

7.1 List of references

7.1 List of references

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