Application of TOPSIS, AHP and GIS in a Multi-Attribute Model to Solve Location Problem for Bank Branches: An Empirical Study in Iran

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Abstract

A selection of suitable locations to establish bank branch is very significant issue from the view point of marketing and long term investment. Because of the complexity of the civic texture and effects of different factors, multi-criteria decision making (MCDM) methods are needed to solve such problems. In this paper, a TOPSIS1 model is designed to solve the complexity of branch selection for Agriculture Bank in Tehran, Iran. This method prefers the alternatives by quantifying criteria and it applies the analytical hierarchy process (AHP) method for determining the importance coefficient of the weight of any effective factor in 20 regions of Tehran. Then, based on the factor's weight obtained by AHP, these 20 regions are ranked and prioritised. In the next step, selection of the regional locations for establishing the bank's branches is carried out. The most important and preference points in a region are chosen and then evaluated by the use of geographic information system (GIS). The potential and suitable points are determined and then prioritised. The region 16 is selected as the first preference based on AHP and TOPSIS models. Also, 63 points of region's important points are referenced and evaluated by the GIS software

Key words: MCDM, Location, AHP, TOPSIS, GIS, Preference bank branches.

Introduction

Today's complex business environment pushes organisations to use scientific methods in order to try and arrive at optimal decisions rather than rely on haunches or arbitrary decision criteria. One of the most important decisions is selection of the best location to reduce costs (such as transportation) and increase the service level. The best location for establishing a bank branch in the metropolitan city of Tehran (with population of more than 10 million) depends on many factors. Therefore, application of complex and scientific method is necessary.

Iran Agriculture Bank is a government bank which is under the supervision of the Bank General Assembly and subsequently the Supreme Council of Banks. The authority is then transferred to Managing Directors and Board of Directors of the bank. There are 11656 employees in Iran Agriculture Bank, working in 23 divisions, at the head provincial directorates and 1690 branches throughout the country. These branches provide diverse banking services like extending credit facilities in the form of Islamic Contracts, opening different types of saving accounts, term deposit accounts, providing check fax services, accepting water, electricity and telephone bills and providing services for draft payments. By the end of the year 1998, the balance of credit facilities extended by the bank exceeded 9 thousand billion Rials (equal to 1.125 billion US Dollars).

In the past, Agriculture Bank was acting more or less as a credit distributor. However, in recent years, in order to cope with increasing demand in the agriculture sector as well as to maintain a sustainable flow of credit to finance the credit requirements of the sector, resource mobilisation through absorbing savings and deposits has become pivotal to the Bank.

For this purpose, the Bank has taken certain measures such as expanding its branch network, organisational restructuring, and deposit mobilisation throughout banking services. It also designed new financial products and services such as issuance of checks and provision of check fax service. As a result of these measures, by the end of 1998, the volume of the bank deposits exceeded 3900 billion Rials, covering 40 percent of the total credit facilities extended by the bank. It was only 20 percent during the year 1991.

The city of Tehran was accorded the highest priority in the investment decision for opening new branches. After this decision, the selection of the best location for building a branch needed to be considered, because it has important effects on marketing and long term prevail. The Iran Agriculture Bank decided to develop a comprehensive location model to analyse different attributes, and thereby find the best location to establish new branches in Tehran. This model should consider factors related to marketing (like closeness to shopping centres, parking lots …) and also other factors such as competitor banks and its own branches.

Location literature search

Most of the location models and procedures which have been designed attempt to define the optimal position of the company in an area or allocation of the company's area for its departments. A few models also have been designed to determine suitable places for service departments and public facilities. However, most of these consider transportation costs as the main criteria [Chapman (1992)]. Location and allocation models can be categorised in three groups. The first category comprises the models that are looking for the minimum distance between company and material resources. In a sense, the goal in these models is minimising material transportation. The second group comprises models which were introduced mostly after World War II, looked for the minimum distance between company and market. This idea is suitable for industries for which the product transportation is the most important factor. Finally, the last group has models that search for an equilibrium between costs and benefits [Mirchandani and Chalton (1989)].

Numerous location models are used for plant location and in some cases just ordinary MCDM methods have been used. In these cases, factors like facilities investment, human resources and land expenses, cost of transportation, and infrastructure are considered [Canel and Das (2002), ReVelle et al. (1977), Mazzarol and Choo (2003)]. However, only a few models allocate to public facilities such as location of gas stations, schools, and bus stations, land value such as Clarkson, et al (1996). Some researchers have developed models which are based on GIS or zero-one programming. In addition, other mathematical models such as Set Covering and Average Number of Facilities have been introduced [Almossawi (2001)].

Any location model has its own advantages and disadvantages and one should apply the model based on the type of problem and its constraint. In some references models are classified in continuous and discrete models [Chapman (1992)] and some are mentioned as fractional and discrete models [Love et al (1988)]. However, investigation regarding service facilities is rare and the model related to location of a bank has not been seen in published literature and the present model is the first model in which the subject is analysed based on scientific methods.

It must be mentioned that, in order to gain maximum benefits, different location methods have been analysed and integrated in a comprehensive model. In the first step, it was assumed that, all people in the city will pass through junctions, squares, important points such as markets, stations etc. This assumption is the most important factor to attract customers by many references [Gerrard and Gunningham (2001), Ta and Har (2000), Cappanera (2003), Harper et al (2005)]. In addition, this helps the designer to simplify the model and decrease the time of calculation because limited important points are chosen in the big city like Tehran. The task of identifying the important places in Tehran has been delivered to GIS device. GIS is the best device to determine points and suitable areas for location research and typically inter-town facilities. However, as Tehran has been already divided into 20 regions by the municipality, the task of choosing these regions has been given to combined methods of AHP and TOPSIS. Application of these methods are massively reported in multi-attribute decision making projects such as Razmi et al (2000), Razmi and Ahmed (2003), Chen (2000), and Lai et al (1994). However, combining these to locate public facilities has not been reported before in Iran.

Steps towards TOPGIA modelling

TOPGIA model is the comprehensive model for introducing the best places in the city for setting up bank branches. It includes three sub-models in which each model performs a step toward achieving the main goal. In the first step the concept of AHP has been used. In the second step TOPSIS method is applied and finally, GIS method is employed. Figure 1 shows the details of the methodology and the steps.

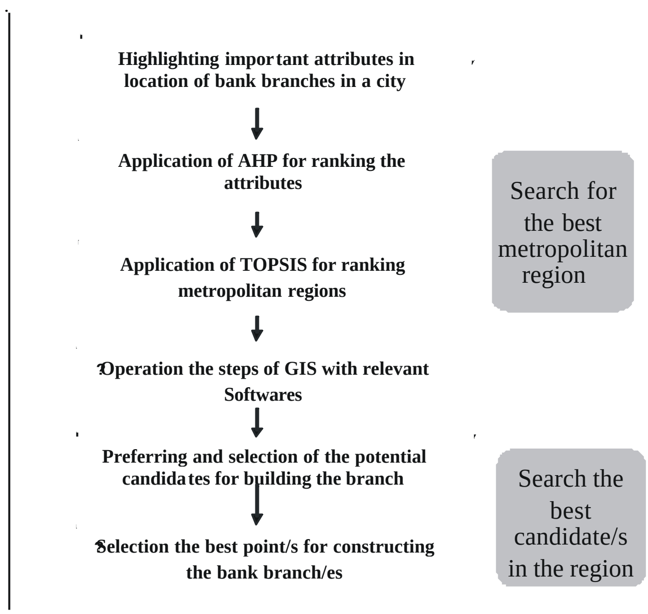


Figure 1: Flowchart of the TOPGIA Model

Step one: Determining preference rate for selected attributes using AHP method.

It is obvious that each region in the city has different potential to attract customers. This relates to the attributes which each region encompasses and these attributes have different effects in this situation. In order to achieve this evaluation, the hierarchy process (AHP) which has been introduced by Saaty (1980) has been used. The AHP is a good qualitative method which can mimic the people's judgment about the preference rate of each attribute.

In order to achieve this evaluation questionnaires were designed and filled in by middle managers of the Agriculture Bank. As a result seven attributes, as shown in the following list were defined. Figure 2 shows the comparison.

1. Number of shopping centres in each region
2. Number of competitors' branches in each region
3. Population of job holders in each region
4. Number of agricultural bank branches in each region
5. Number of parking lots in each region
6. Number of police stations
7. The capacity of the parking lots in each region

According to Saaty (1980), all attributes are next compared pair-wise with each other, according to their levels of influence upon the organisation objective, in order to calculate the weight of each attribute. The decision maker must express his/her preference between each

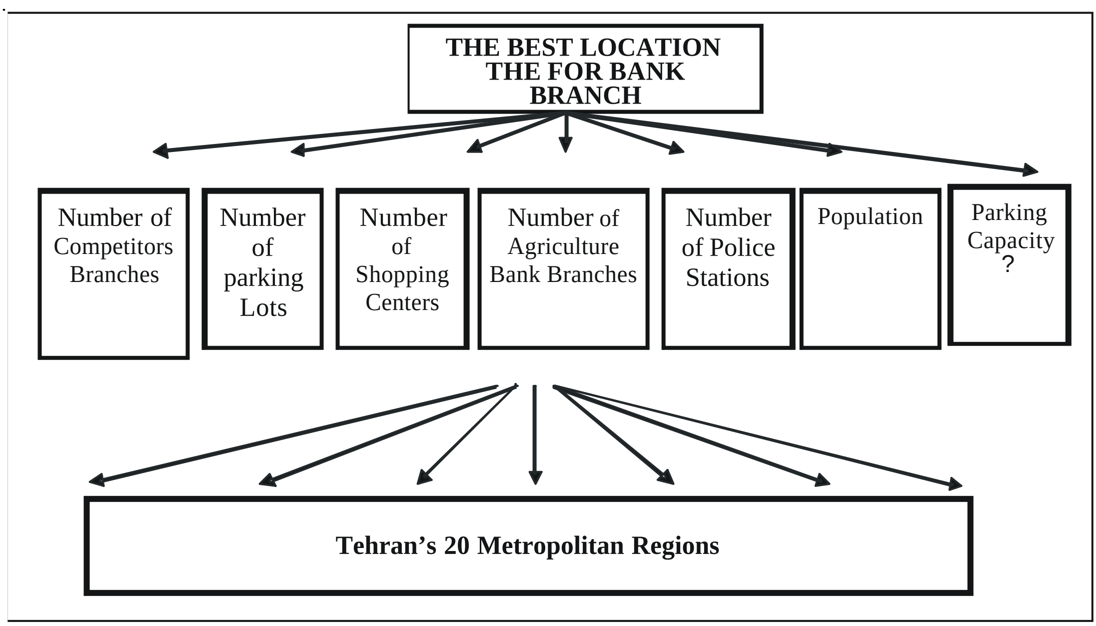


Figure 2: The devised AHP model for location problem of Agriculture Bank

pair of elements. Each pair-wise comparison is scored as: equally important (1), slightly more important (3), strongly more important (5), very strongly important (7), and absolutely more important (9). An even preferential number scoring system can also be used. These comparisons result in a matrix. Then all numbers in every column in the matrix are added up and in order to normalise the matrix all element of the matrix have been divided by the added up number which has been calculated before. Finally, all numbers in the each row (numbers are calculated for each attributes in the normal matrix) are added and these demonstrate the priority weight of each attribute. The final step is to calculate the consistency ratio (CR) for this matrix. If the CR value is less than 0.1, it implies that there is less than 10 percent chance that the elements are compared well [Saaty (1980)]. In this case CR is 0.09, which suggests highly acceptable consistent comparison. All calculations in this section have been performed by Expert Choice Software (revision 2000) for the existing problem and the results illustrated in Table 1.

ATTRIBUTE	WEIGHT	ATTRIBUTE	WEIGHT
1. No. of shopping centers	0.323	5- No. of parking lots	0.071
2. No. of competitors branches	0.206	6- No. of police stations	0.061
3. No. of population with job	0.171	7- Capacity of parking lots	0.054
4. No. of Agriculture Bank branches	0.114	**CONSISTANCY RATION**	**0.09**

TABLE 1: Scores for attributes using AHP Method

Step two: TOPSIS process to rank municipal regions

When all alternatives are ordered, all municipal regions must be compared with each other based upon the attributes' preference role. TOPSIS is one of the best MCDM methods when one wants to decide based upon several quantitative attributes. However, AHP is very useful method for qualitative comparison. In previous step, all the attributes (which cannot be simply compared quantitatively) are ordered. It is obvious that since all necessary data related to the above public facilities exist (i.e. quantitative comparison is available), it is better to engage a quantitative approach to find the best region to set up the Bank branch. The philosophy of TOPSIS is to find the alternative which is next to the best solution and simultaneously is far from the worst solution. The TOPSIS has six stages to complete which are explained in the following.

First stage: Creating the normalised decision making matrix

In this stage, it is attempted to show all the alternatives' data in the table. For example, for this case a table of 7 rows (indication of the attributes) and 20 columns (indication of 20 regions) is the result of this stage. The numbers in the bottom of each attributes show how many of that facility are available in that region.

Second stage: Creation of the weighted normalised matrix

In this stage one must create the table which shows in each region how many facilities exist for each attributes (Table 2 illustrates the number of public facilities in each region). This table illustrates a matrix of 7 columns (7 attributes) and 20 rows (20 districts).

Regions	***Agriculture Bank branches***	***Competitors branches***	***Population with job***	***Shopping centers***	***Parking lots***	***Police stations***	Parking lots Capacity
District No. 1	2	60	63598	7	7	4	2212
District No. 2	7	84	122979	15	1	2	30
District No. 3	6	85	71057	11	3	7	246
District No. 4	4	58	174988	13	1	8	50
District No. 5	3	27	110983	14	1	3	30
District No. 6	15	315	59762	25	17	1	850
District No. 7	5	159	82579	14	16	1	512
District No. 8	1	71	88758	5	5	1	170
District No. 9	0	59	44464	6	17	1	1776
District No. 10	2	79	74147	10	35	1	1925
District No. 11	5	112	64540	16	52	2	3172
District No. 12	7	275	50568	17	89	4	6141
District No. 13	3	48	67805	12	4	1	292
District No. 14	1	12	106853	8	10	2	500
District No. 15	0	40	155648	7	3	1	69
District No. 16	2	59	72476	17	7	4	462
District No. 17	1	32	67716	5	11	2	737
District No. 18	2	27	69887	1	6	1	312
District No. 19	1	11	53350	3	2	1	390
District No.20	1	41	87387	7	1	6	30
Total	**68**	**1705**	**1688515**	**213**	**183**	**48**	**19906**

TABLE 2: Number of public facilities in each region

The importance level of attributes, have been calculated by the AHP method. The importance level of attribute and their behaviours in the model have been shown in Table 3. In this table all attributes are labeled as "desirable" and "undesirable". If any increase in attribute's outcome enhances the organisation profit, that attribute is called "desirable" and vice versa. For example, attribute number two (number of competitors' branches) is labeled as undesirable, since increasing its outcomes saturates the business in that regions and it may not be beneficial.

ATTRIBUTE NUMBER	WEIGHT	TYPE OF ATTRIBUTES' BEHAVIOUR
1 (No. of shopping centers)	0.323	DESIRABLE
2 (No. of competitors branches)	0.206	UNDESIRABLE
3 (No. of population with job)	0.171	DESIRABLE
4 (No. of Agriculture Bank branches)	0.114	UNDESIRABLE
5 (No. of parking lots)	0.071	DESIRABLE
6 (No. of police stations)	0.061	DESIRABLE
7 (Capacity of parking lots)	0.054	DESIRABLE

TABLE 3: Attribute's behaviors and their weights

Third stage: Calculation of the best and worst solutions

Based upon TOPSIS process, in this stage the best solution and the worst solution must be determined based on every individual attribute [Franklin (1998)].

According TOPSIS algorithm, table 2 first must be normalised and then based upon the importance level of each attribute (shown in Table 3) and the role of each attribute as a benefit or cost in the model the following matrix (The weighted normalised matrix) is determined (Table 4). Since the first two attributes in the table have negative impact on the model, TOPSIS looks for the minimum values in these columns. So the regions 9 and 15 in the first attribute and region 19 have been selected as the best locations. However, the other 5 remaining attributes have positive impact on the model and TOPSIS looks for the maximum values. Therefore, regions 4, 6, 12, 4, 12 have been selected as the best locations based on the remaining attributes respectively.

Regions	Agriculture Bank branches	Competitors branches	Population with job	Shopping centers	Parking lots	Police stations	Parking lots Capacity
District No. 1	0.01058	0.02404	0.02678	0.04186	0.00437	0.01789	0.01518
District No. 2	0.03705	0.03366	0.05178	0.08971	0.00062	0.00895	0.00021
District No. 3	0.03175	0.03406	0.02992	0.06579	0.00187	0.00895	0.00169
District No. 4	0.02117	0.02324	0.07368	0.07775	0.00062	0.03578	0.00034
District No. 5	0.01588	0.01082	0.04673	0.08373	0.00062	0.01342	0.00021
District No. 6	0.07938	0.12622	0.02516	0.14951	0.01060	0.00447	0.00583
District No. 7	0.07646	0.06371	0.03477	0.08373	0.00998	0.00447	0.00351
District No. 8	0.00529	0.02845	0.03737	0.02990	0.00312	0.00447	0.00117
District No. 9	0.0000	0.02364	0.01872	0.03588	0.00748	0.00447	0.01218
District No. 10	0.01058	0.03165	0.03122	0.05980	0.02183	0.00447	0.01321
District No. 11	0.02646	0.04488	0.02675	0.09569	0.03243	0.00895	0.02176
District No. 12	0.03705	0.11019	0.02128	0.10167	0.05550	0.01789	0.04213
District No. 13	0.01588	0.01923	0.02855	0.07177	0.00249	0.00447	0.00200
District No. 14	0.00529	0.02524	0.04499	0.04784	0.00624	0.00895	0.00343
District No. 15	0.00000	0.01603	0.06554	0.04186	0.00187	0.00447	0.00047
District No. 16	0.01058	0.02364	0.03052	0.10167	0.00437	0.01789	0.00317
District No. 17	0.00529	0.01282	0.02851	0.02990	0.00686	0.00895	0.00506
District No. 18	0.01058	0.01082	0.02943	0.00598	0.00374	0.00447	0.00214
District No. 19	0.00529	0.00441	0.02246	0.01794	0.00125	0.00447	0.00268
District No.20	0.00529	0.01643	0.03679	0.04186	0.00062	0.02684	0.00021

TABLE 4: The weighted normalized matrix

Now, one must realise which region has got the worst values in each attribute (Table 5). This process is vital in order to calculate the proportional vicinity of each region in each attribute.

ATTRIBUTES		1	2	3	4	5	6	7
THE BEST SOLUTION	A^+	0.0	0.004	0.0736	0.149	0.0555	0.0357	0.0421
THE WORST SOLUTION	A^-	0.0793	0.0126	0.0187	0.0059	0.0006	0.0044	0.0002

TABLE 5: The best and the worst solutions

The Forth stage: Calculation of the distance between the best and the worst solution

In this stage, the distance between the best and the worst solutions for all metropolitan regions have been calculated [Franklin (1998) and Olson (2004)] and the result is shown in Table 6. The following formulas have been applied to calculate the second and the third column of the table 6 respectively:

$$S_i^- = \sqrt{\sum_{i=1}^{n}(wi - w_i^-)^2}$$

$$S_i^+ = \sqrt{\sum_{i=1}^{n}(wi - w_i^+)^2}$$

$$C_i^* = \frac{S_i^-}{S_i^- - S_i^+} \text{................} 0 < C_i^* \leq 1, \ldots\ldots i = 1,2,\ldots\ldots,n$$

Fifth stage: Calculation of proportional vicinity to best solution

In this stage, the distance of each alternative from the worst solution must be divided by the sum of distance of that alternative from the best solution and the worst solution. In the other words, this calculation shows which alternative is next to the best solution and simultaneously is far from the worst solution [Franklin (1998)]. The result of this calculation is shown in the fourth column of the Table 6.

Sixth stage: Ranking the results

In the last stage, all scores from the previous stage must be ranked respectively. In this case, as it can be seen from the last column on the table 4, the regions number 16, 5, 4, 11 etc. have the priority for construction of the branches with scores of 0.623, 0.602, 0.595, 0.591, etc. respectively.

METROPOLITAN REGIONS	DESIRABLE DISTANCE CRITERIA	UNDESIRABLE DISTANCE CRITERIA	FINAL SCORES	Region ranks for Investment based on Final Score
	S^+	S^-	PL	
1	0.13397	0.13017	0.493	11
2	0.10851	0.13595	0.556	5
3	0.12667	0.12036	0.487	15
4	0.1035	0.15213	0.595	3
5	0.10304	0.15575	0.602	2
6	0.16675	0.14413	0.464	18
7	0.12084	0.11449	0.487	14
8	0.14708	0.12639	0.462	19
9	0.14313	0.13382	0.483	16
10	0.11686	0.13171	0.530	7
11	0.09542	0.13793	0.591	4
12	0.13385	0.12713	0.487	13
13	0.11813	0.1411	0.544	6
14	0.12754	0.13487	0.514	9
15	0.13184	0.14807	0.529	8
16	0.09533	0.15733	0.623	1
17	0.14459	0.1382	0.489	12
18	0.16725	0.13483	0.446	20
19	0.15951	0.14314	0.473	17
20	0.13406	0.1402	0.511	10

TABLE 6: Distances between the best and the worst solution

Application of Geographical Information Systems (GIS) in this project

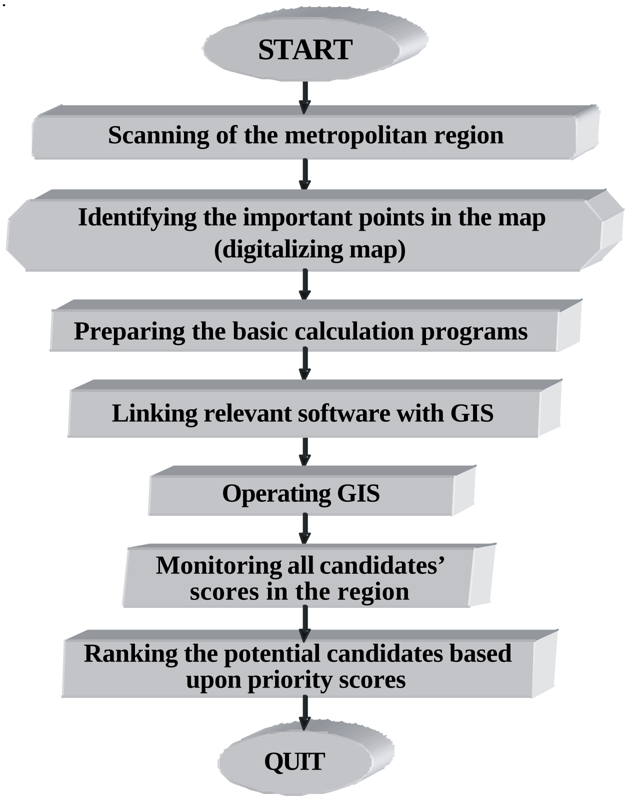
Geographical Information Systems (GIS) actually contains the subjective information location systems for each geographical area which can be applied to find the optimal location [Von Meyer (2004), and Bolstad (2002)]. Some GIS softwares have been introduced which have be engaged to find the best places and their application shows high efficiency of their system in such problems. The input of the GIS is the combination of maps and geographical information in which the subjective information related to every physical point is written independently. Figure 2 shows the logic of the GIS process to solve the location problems. The main objective of using GIS in this project is to allocate the best location in Tehran's metropolitan region number 16 to construct the Agriculture bank branches based upon the predefined attributes such as closeness to shopping centres, parking lots, etc. The process to obtain the above goal is illustrated in the following.

Quantification

In the first, the map of the region 16 has been scanned and based on the number of public facilities in the region all information has been quantified. As explained before, GIS can highlight all specifications in the city. But in this study, intentionally, only attributes which are predefined such as, shopping centres, police stations, intersections, squares, etc. are highlighted in the GIS. This task has been accomplished by using AUTOCADMAP 2000.

Building the region's Topology

In order to build the topology of the region ARCINFO software has been applied. In the initial step, the output of AUTOCADMAP with D*F format has been modified to ARC format in ARCINFO and then the topology of the region has been built.



Modelling

In this study, (based upon GIS methodology) eight information layers have been considered (see Table 7). In other words, on the scanned map of region 16 (layer eight) all information about streets, competitors' branches, shopping centres, etc. has been highlighted in a digital format which is the basic requirement for running GIS.

Layer one: Boulevards and main streets	Layer five: Own branches
Layer two: Competitors' branches	Layer six: Parking lots
Layer three: Shopping centers	Layer seven: Potential candidates
Layer four: Police stations	Layer eight: Scanned map of region 16

TABLE 7: Eight Layers of Information

Since two attributes of population and parking capacity are not defined in existing Tehran's GIS package, only five attributes (shown in Table 8) have been considered in this model. Therefore, the AHP weights must be modified in this case. Assume these attributes have the same effect on the system, and then dividing every individual weight by the sum of the selected attributes (0.775) will indicate the new modified weight. For example, the new weight for closeness to shopping centre is (0/323/ 0.775=0.42). Table 6 illustrates the modified weights for selected attributes. It is obvious that theoretically infinite points can be defined in a finite location/space and logically searching the best point in a location (like metropolitan region of 16) is not possible. Besides, it is not practical. So a radius of 1500 metres has been defined as a point for the computer. In this way region is compartmentalised into 63 points. In other words, each point is a potential location to construct the new bank branch.

ATTRIBUTES	WEIGHT
No. of shopping centers	0.42
No. of police stations	0.08
Capacity of parking lots	0.09
No. of competitors branches	0.27
No. of Agriculture Bank branches	0.14
The Search Radius	1500 meter
Total number of points in region 16 based upon 1500 meter Search radius	63

TABLE 8: Attributes undertaken in GIS Study

Before running the model, two managerial concepts related to competitors' bank branches and existing Agriculture Bank branches are introduced. Some managers believe that the new branch must be constructed next to competitors' branch, since they probably already calculate the optimal place for investment. Others believe that there are pioneering (unused) places which can attract new customers and it is better to look for them. In order to respond to these visions, the model has been executed based on two scenarios. In the first scenario "A", the best candidate should be close to the competitors' branches, and in the second scenario "B", the best candidate should not be close to the competitors' branches

The GIS model has been run based upon two scenarios and the output of ARCINFO software is transferred to ARCVIIEW. Then all scores for each specific point in the region (in two scenarios) have been calculated. Based upon the above study, candidate number 61 (Javadieh St.) and candidate number 62 (Naziabad St.) respectively in scenarios of "A" and "B" are highlighted as the best points for construct the Bank branches.

Conclusions

This study illustrates a practical location case study to highlight the best place to construct a new branch of Agriculture Bank in the metropolis of Tehran. It has been shown that this is a multi-criteria decision making

(MCDM) problem. In order to obtain the advantages of the best MCDM methodologies, we attempted to combine three tools of AHP, TOPSIS and GIS. The AHP has been applied for prioritising the attributes in a qualitative approach. TOPSIS has been used to rank 20 Tehran's metropolitan regions in quantitative manner. Finally, GIS has been applied to evaluate all points in the region which have been selected by TOPSIS. This study answers the following questions:

- Which attributes have priority in location of the Bank branches in the public areas?
- Which regions have the priority to invest?
- How suitable is the distribution of the existing branches?
- Regarding two scenarios, which points of optimal regions are more reasonable for establishing the Bank branches?

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