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A GIS-Based Sites Selection with Maximal Covering Location Problem for bank branch Development

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Abstract

Selecting a location is a very important decision for firms because they are costly and difficult to reverse. A poor choice of location might result in excessive transportation costs, loss of qualified labor, competitive advantage or some similar condition that would be detrimental to operations.This paper proposed integration between MCDM model represented by ANP with GIS to propose the best location for construction of a new bank branch and then using maximal covering location problem to select branches that the maximum demand might be reached within a pre-specified target travel time. Bank branch location is one of the most significant strategic issues in the competitive market. In this paper, a Geographic Information System (GIS) based model for locating suitable sites is presented to make new branches, and then maximal covering location problem (MCLP) is used to select branches such that the maximum demand might be reached within a pre-specified target travel time. The model was implemented for Mehr Eqtesad bank in Arak city, Iran. In the future research, it is recommended to study reconstruction of bank branches. Moreover, applying this model on more complex problems is a challenging area for future studies.

Keywords: Location, Geographic Information System, Esri ArcGIS for Desktop ١٠, Maximal Covering Location Problem

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١. Introduction

Selecting a location is a very important decision for firms because they are costly and difficult to reverse. A poor choice of location might result in excessive transportation costs, loss of qualified labor, competitive advantage or some similar condition that would be detrimental to operations [١]. Locating an economic activity, including a retail firm, factory, service center, etc. is one of the most important questions facing an economic firm, as this issue can determine the success or failure of a firm [٢]. The first theory of land use, proposed by Van Tannen in his book The Single State in ١٨٢٦, was assumed to be in a land with perfectly uniform and homogeneous characteristics, ideally in the center of the city. Will be located and the city will be developed in the form of concentric circles around it [٣]. Banks, as part of the economic organizations that communicate with the people on a daily basis, are particularly sensitive to choosing the right location for branches to maximize their market share with competitors and increase customer satisfaction[٢]. Due to the increase and intensity of competition, providing services in places and locations desired by customers is a determining factor in attracting and retaining customers [٤]. Decision support systems (DSS) incorporate both data and models. They couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions and to support managerial judgment [٥]. Location analysis with the increased availability of computer-based tools can provide inestimable information to help firms for improving their decision-making process. Integration between Multicriteria Decision Making (MCDM) and GIS is needed to solve the site selection problem, as GIS is used to handle the spatial aspect of the problem and MCDM is used to calculate weights of the criteria and ranking of alternatives [٦].

Extensive studies have been reported associated with investigated the problem of location using integer programming model and covering location problems. Jafarnejad et al. [٥] used geographic information system for a warehouse site selection decision. Aldajani and Alfares [٧] investigate the problem of determining optimum number and locations of ATMs by the help of GIS and covering models. Zielsdorf [٨] used GIS to analyze potential markets within the seven counties that make up the Twin Cities metropolitan area. He used a GIS-based, weighted model with demographic data to find the best location for marketing to potential and current customers, while concurrently isolating the most optimal location to focus first marketing efforts. It was determined that high-earning families with children offer the most potential for expanding, or attracting customers to a multitude of banking products that include savings bonds, retirement accounts, college savings funds, regular savings accounts and certificates of deposit. Meyer [٩] examines the current location of fire stations that deploy fire protection and emergency medical services in Toledo, Ohio. He tries to improve the efficiency of coverage to decrease total travel times. He employs the methodologies of the MINISUM location allocation strategy and uses maximum distance restriction to exclude long and unacceptable response times, increase efficiency of emergency services, and reduce response times, thus increasing overall effectiveness in service delivery. This study implements with a Geographic Information System. Mahmud and Indriasari [١٠] proposed a model to maximize total service area of a fixed number of facilities. Two Greedy algorithms, Greedy Adding (ADD) and Greedy Adding with Substitution (GAS), were applied to solve the optimization problem of the Maximal Service Area Problem (MSAP). They implemented this model for determining fire station locations in Jakarta Selatan, Indonesia. Alsalloum and Rand [١١] used Maximum Covering Location Problem to identify locations of emergency medical service stations so that the maximum demand might be reached within a pre-specified target travel time. Farkas [١٢] discussed Expert systems, geographic information systems and multi-criteria decision tools to support route/site selection problems. A hierarchical decision tree model prepared to join the diverse engineering, economical, institutional and social perspectives as well as the environmental objectives. A comprehensive example of the route/site selection process of a metro-rail network project is also presented. Ibrahim [٦] investigated selecting the best location for wastewater lift station of an under-construction industrial sewage system in El-Mahalla El-Kubra, Egypt. They used experts' judgment sand fuzzy Analytical Hierarchy for weighting criteria. GIS was also used to overlay and generate criteria maps and suitability map. The study ends with an assessment of proposed sites to the generated suitability map.

As we know, little research has been done in bank branch locating, especially in Iran. In this paper, an integrated procedure of MCDM, GIS and maximal covering location problem will be presented, which introduces a new method in locating problems.

١.١. Geographic Information Systems Applications

Computerized map scans display hidden relationships between customers or competitors and territories [٥]. Geographic information systems (GIS) are suitable for location due to their high ability to manage the volume of spatial data from different sources[١٧]. The use of spatial information systems is not possible without the use of conceptual and mathematical models [١٣]. In general, a GIS is used to collect, store and analyze information whose geographical location is a key feature. In other words, this system is used to collect and analyze all information that is somehow related to geographical location [١٩]. This system is also the most important tool in providing statistics and information in the form of visual statistics[٢٠].

١.٢. Covering Models

The simplest form of covering models is the location set covering problem (LSCP), which seeks to position the minimum number of facilities that are necessary to cover all demand areas within S distance or time units. A related problem is the p-center problem (PCP), which seeks the location of p facilities such that the maximum distance (time) from any demand area to its nearest facility is minimized. Location covering models generally address the location of urban public facilities. Both LSCP and PCP require that all demand areas be covered, and this may require excessive resources not always available to the public authorities. MCLP does not require that all demand areas be covered [١٤]; Using hierarchical analysis methods, fuzzy algorithms and GIS tools, researchers have tried to find suitable places in different cities of Iran, which can be found in Nemati et al. [١٥], Seidaei et al. [١٦], Razavian et al. [١٨] pointed out.

٢. Problem Definition

In this paper, we obtained criteria from literature review and applying DEMATEL and ANP for criterion weighting. In the next step for GIS analysis, the GIS software Esri ArcGIS for Desktop ١٠ and various GIS layers were used. The GIS layers represent each of the criteria to be used in the GIS analysis. To manage the analysis, we must make sure that sufficient GIS data are available; otherwise, we must develop the GIS layers. While map-making preparation, multiple geographic layers are aggregated to produce maps that show the suitability of the land for making new bank branch. Finally, we must use maximal covering location problem (MCLP) to select branches so that maximum demand might be reached within a pre-specified target travel time.

٢.١. Case Study

The study area is Arak metropolis, a city in and the capital of Markazi Province, Iran. It occupies an area of approximately ٧٠٠٠ ha. The area extends from ٣٤°٥'٣٠" north to ٤٩°٤١'٣٠" east. Also, Mehr Eqtesad bank is one of the private Iranian banks. We researched an algorithm for locating new bank branches and simulated this model for Mehr Eqtesad bank in Arak metropolis.

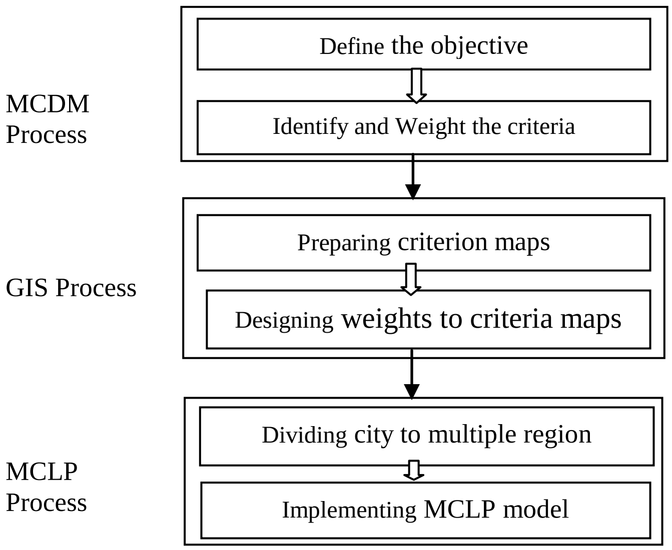

Figure١. The proposed methodology

٢.٢. Define the Objective

The first stage in managing a multi-criteria evaluation analysis is to define the objective of the analysis. In this paper, the objective is to present a model for locating a new bank branch.

٢.٣. Identify and Weight the Criteria

In this step, important criteria in locating new bank branch were determined with five clusters and eleven criteria include: Population Characteristic (Population density, Income level), cost (Cost of Purchase or rent branch's build), urban facilities accessibility (Hospital and medicine vicinity, Business center vicinity, Hotel and tourism center vicinity, Office and company vicinity, Parking vicinity), transportation system (taxi/bus stop and metro/monorail vicinity, Main Way vicinity) and competition (c**ompetitor branch** vicinity), also weights of each criteria were determined by a group of experts using the pairwise comparison matrix of the Analytic Network Process. The inconsistency rate of the pairwise comparison matrix was controlled to be less than ٠.١.

٣. Preparing criterion maps

By using the Arak city GIS map extract, some needed criteria layer and some of them (income level, Cost of Purchase or rent branch's build) are made by self-knowledge about Arak city. We made GIS vector layers for all eleven considered criteria. Convert all vector layers to raster format because the GIS software used to manage the analysis (Esri ArcGIS for Desktop ١٠) is a raster-based GIS. Some of GIS layer shown in Figures ٢, ٣, ٤, ٥, ٦ and ٧.

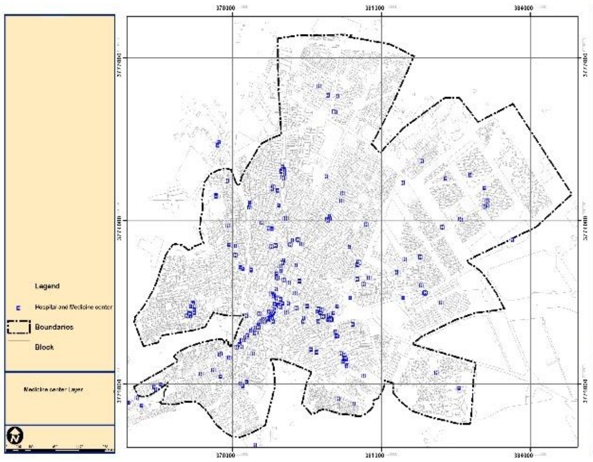

Figure ٢. Hospital and Medicine center layer

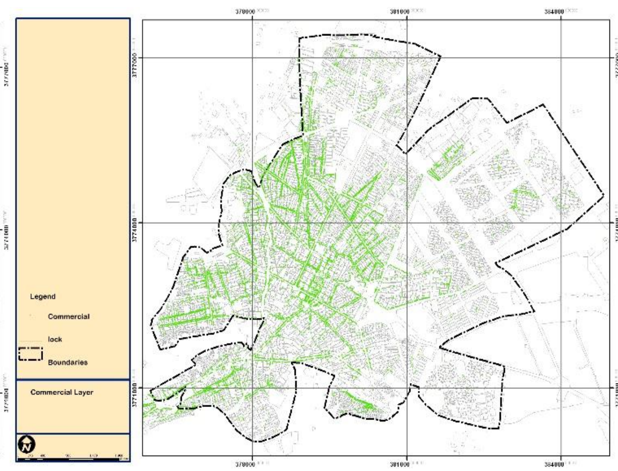

Figure ٣. Business center layer

Figure ٤. Population density layer

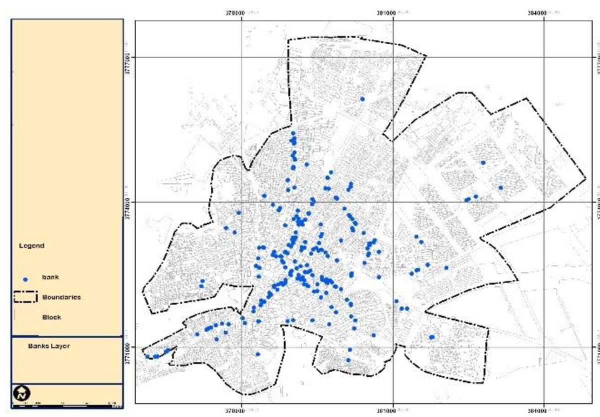

Figure ٥. Competitor bank branch

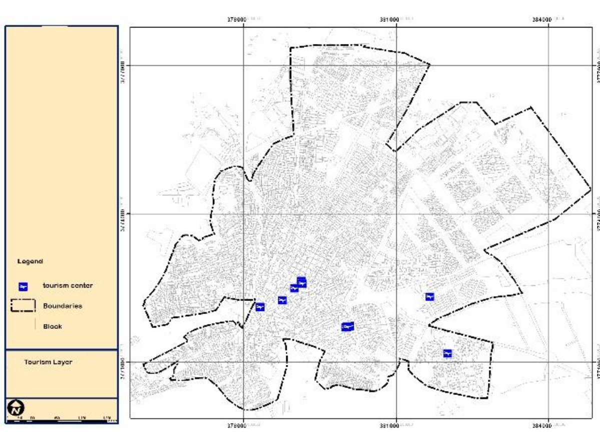

Figure ٦. Hotel and tourism center layer

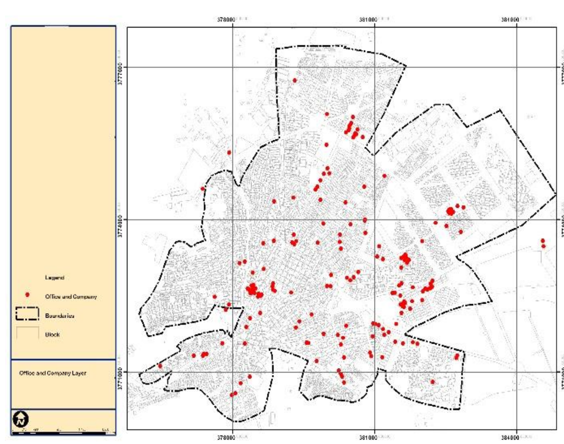

Figure ٧. Office and company layer

٣.١. Designating Weights to Criteria Maps

The next step to generate the map is allocating weighting to criteria maps in the GIS software. Esri ArcGIS for Desktop ١٠ was used to conduct the analysis and produce the map. The following technical steps have been done according to Decision Support Wizard of Arc GIS, according to distance to own branch, classify all eleven criteria and also vicinity to familiar branch criterion to High suitable, suitable and non-suitable classes, and define an importance value for each class that sequencely are ٠.٦, ٠.٤ and zero. We used the distance tool in ARCGIS software to put on every value and distance according to Table ١, on their criteria layer. Finally, every important criterion obtained in the previous step was multiplied at its layer and then all layer multiplied at each other to getting best locations for making a new branch.

Table ١. Classification of criterion distance to own bank branch

Criteria / Suitability	High suitable	Suitable	Non-suitable
Main street	≤١٠٠m	١٠٠-٥٠٠ m	≥٥٠٠ m
Business center	≤١٠٠m	١٠٠- ٢٥٠ m	≥٢٥٠ m
Hotel and tourism center	≤١٠٠٠m	١٠٠٠-٣٠٠٠ m	≥٣٠٠٠ m
Office	≤٢٥٠m	٢٠٠-٥٠٠ m	≥٥٠٠ m
Competitor branch	١٠٠-٢٠٠ m	≥٢٠٠m	≤١٠٠ m
Familiar branch	≥١٠٠٠m	٥٠٠-١٠٠٠m	≤٥٠٠ m
Income level	High	Middle	Low
Cost of purchasing building	Middle	High	Low
Medicine center	≤١٠٠m	١٠٠-٥٠٠m	≥٥٠٠ m
Population density	≥٥٠٠	٢٠٠- ٥٠٠	≤٢٠٠
Parking	≤٥٠٠ m	٥٠٠- ١٥٠٠ m	≥١٥٠٠ m
Bus/taxi/metro vicinity	≤٥٠٠ m	٥٠٠- ١٥٠٠ m	≥١٥٠٠ m

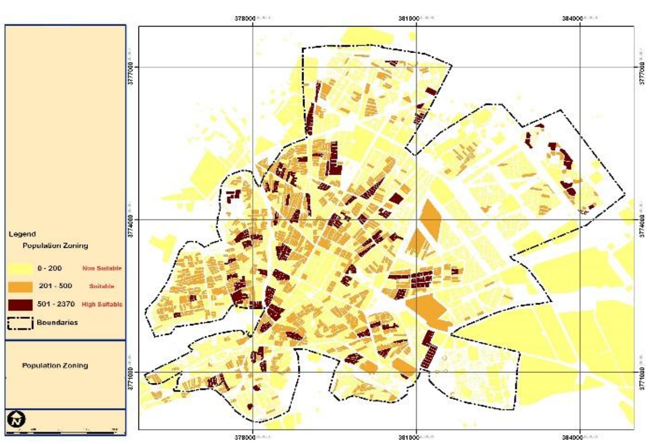

Figure ٨. Income level zoning

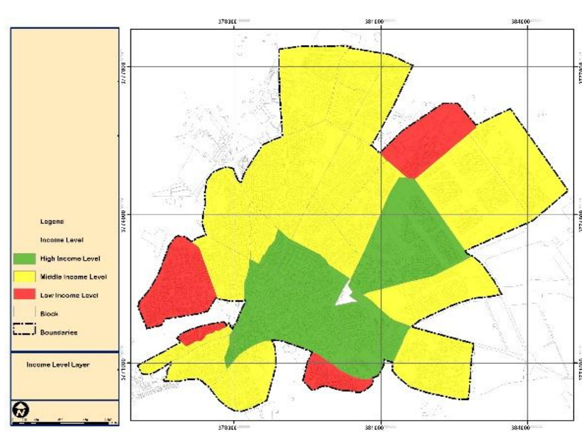

Figure ٩. Population density zoning

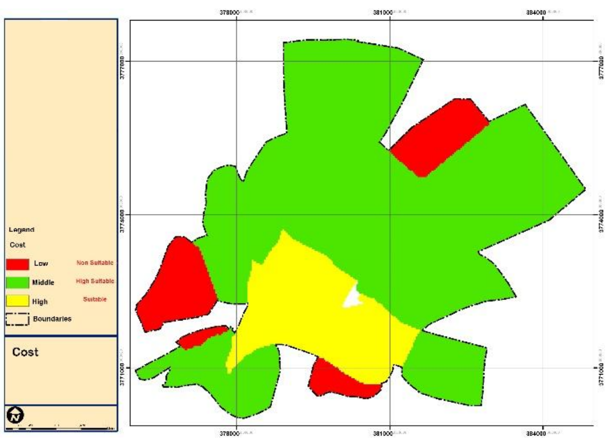

Figure ۱۰. Cost of land purchasing zoning

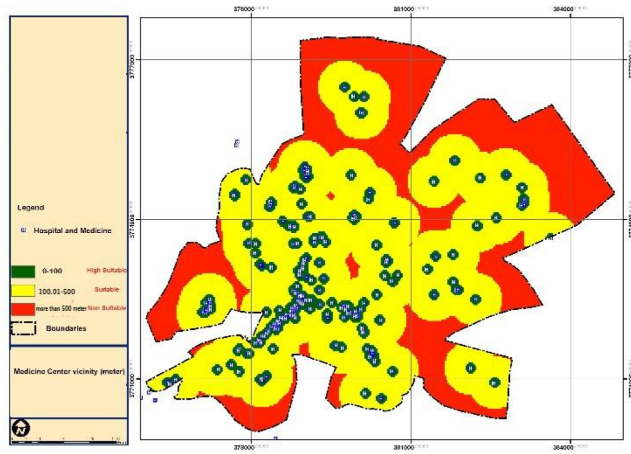

Figure ۱۱. Medicine center zoning

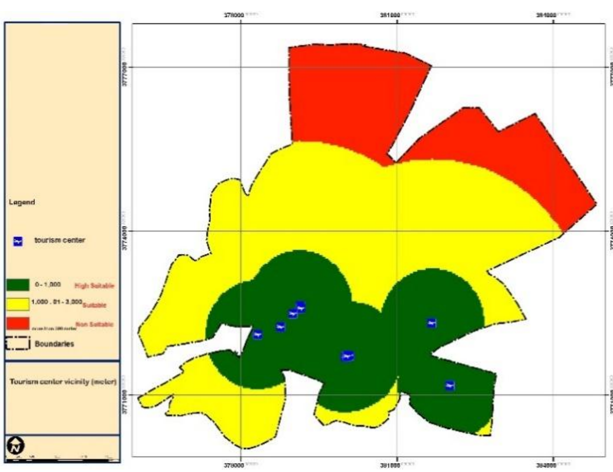

Figure ۱۲. Hotel and tourism center zoning

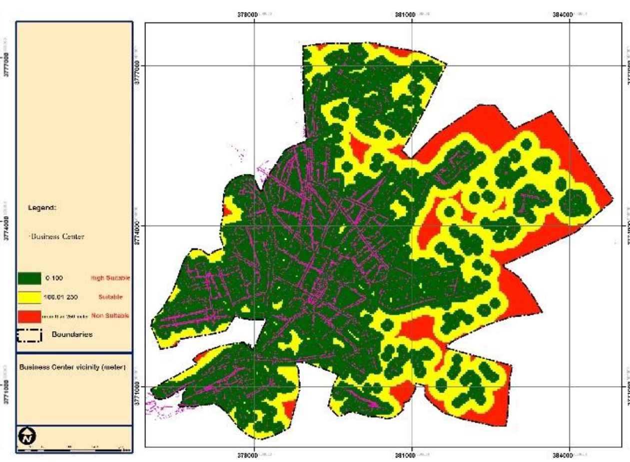

Figure ۱۳. Business center zoning

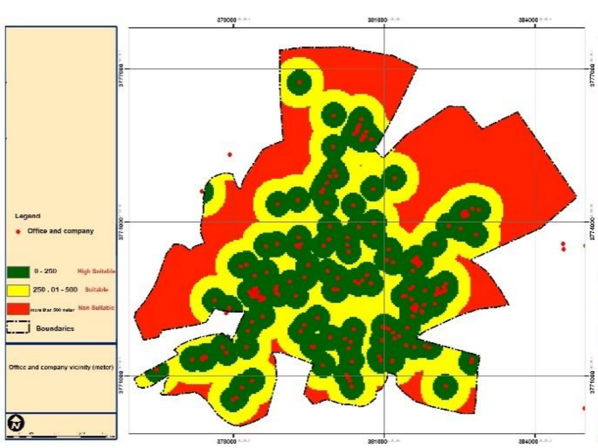

Figure ۱۴. Office zoning

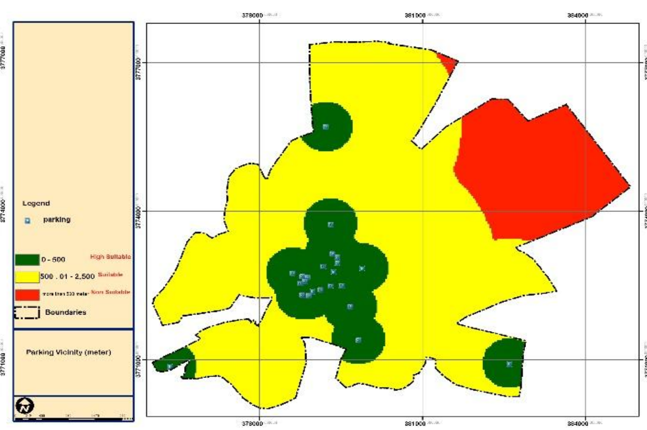

Figure ۱۵. Parking zoning

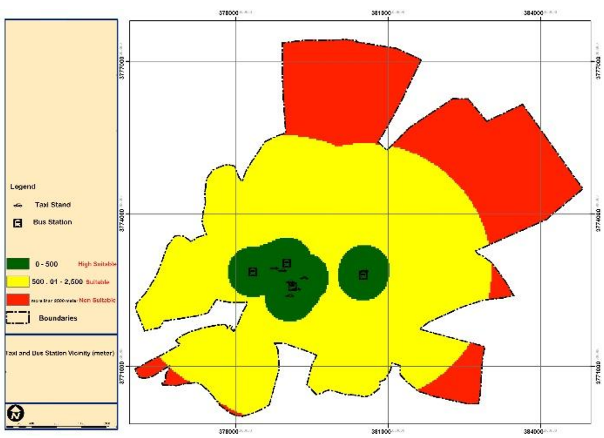

Figure ١٦. Bus/taxi zoning

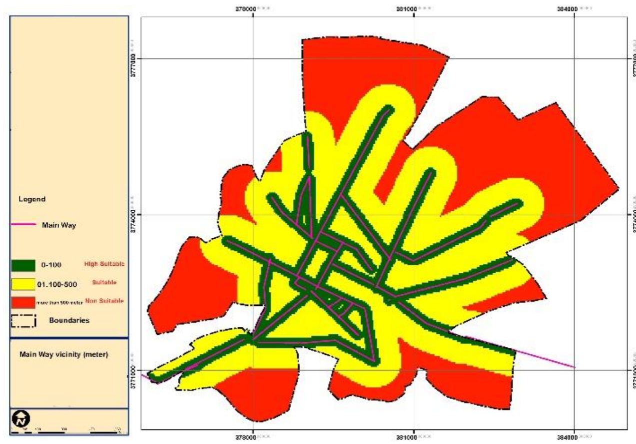

Figure ١٧. Main street zoning

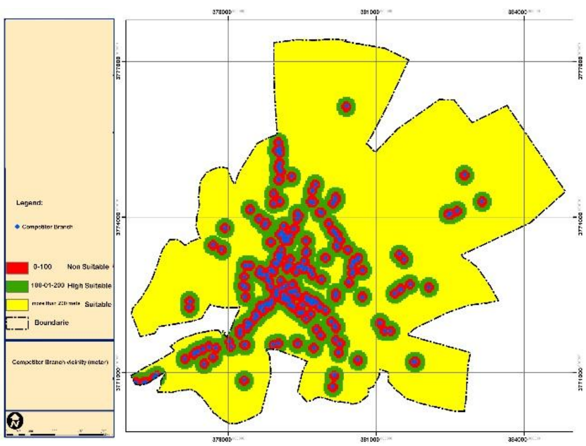

Figure ١٨.Competitor bank branch

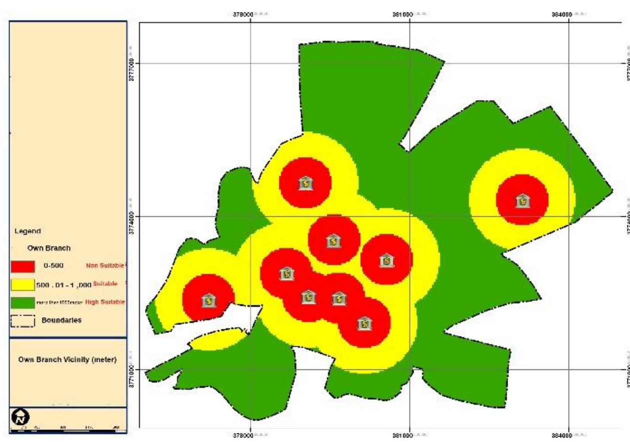

Figure ١٩. Current own bank branch

٣.٢. Set of Candidate Sites

After designating weighting to criteria map steps, ARC GIS proposed sites for making a new branch. In addition, it classified these sites into three class include first priority, second priority and third priority according to their scores. There are ٢٣ candidate sites available in the study area, consisting of ١٤ proposed sites and ٩ sites of existing bank branches.

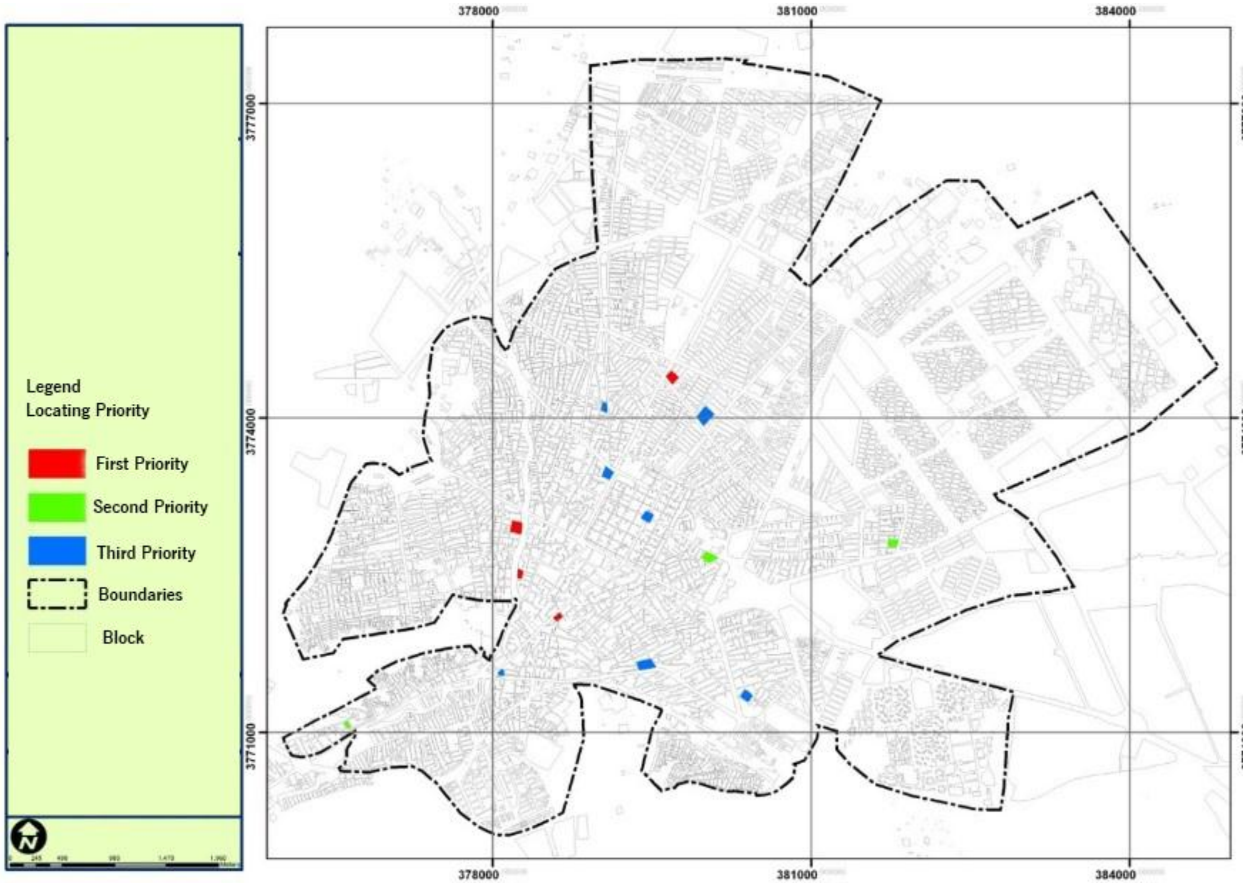

Figure ۲۰. Proposed site for making new branch by ARCGIS software

۳. Using Maximal Covering Location Problem

In this section, the goal is applying maximal covering location problem. For using MCLP according to municipality traffic section, divide the city into twenty sections (twenty demand areas) and do not consider the priority of located site. A mathematical formulation of this problem can be stated as follows:

Maximize $z = \sum_{i \in I} a_i y_i$

s.t: $\sum_{j \in Ni} a_{ij} x_j \geq y_i$ for all i ϵ I

$\sum_{j \in J} x_j = p$

$x_j = (۰, ۱)$ for all j ϵ J

$y_i = (۰, ۱)$ for all i ϵ I

Where

I = the set of demand area

J = the set of candidate branch;

a_{ij} = the coverage coefficient

$$a_{ij}=\begin{cases}1 & \text{if demand area } i \text{ covered by candidate branch } j\\ 0 & \text{otherwise}\end{cases}$$

$$y_i=\begin{cases}1 & \text{if demand area } i \text{ is covered by at least one candidate branch}\\ 0 & \text{otherwise}\end{cases}$$

$$x_j=\begin{cases}1 & \text{if a candidate branch alocated to demand area } j\\ 0 & \text{otherwise}\end{cases}$$

a_i= population to be served at demand area i;

p= the number of facilities to be located (number of branch can be located).

After formulating problem, solve it using LINGO software. Result of problem with different number of branch can be located (*p*) and percentage of covering shows in Table ٢.

Table ٢. Result of problem with different number of branch can be located and percentage of covering

p	Selected branch	Covering percentage (%)
١	x_p	٩٠
٢	x_t, x_{pm}	٩٦
٣	$x_n, , x_m, , x_t$	١

As shown in Table ٢, approximately ٩٠% of the study area can be covered by making one branch and nearly ٩٦٪ with ٢ branches and ١٠٠٪ of the demand area will be covered by ٣ branches, results exhibit decreasing marginal coverage with each additional branch. In other words, the additional coverage obtained by adding the *k*th branch is generally less than the additional coverage that is obtained by adding the (*k*+١)th branch.

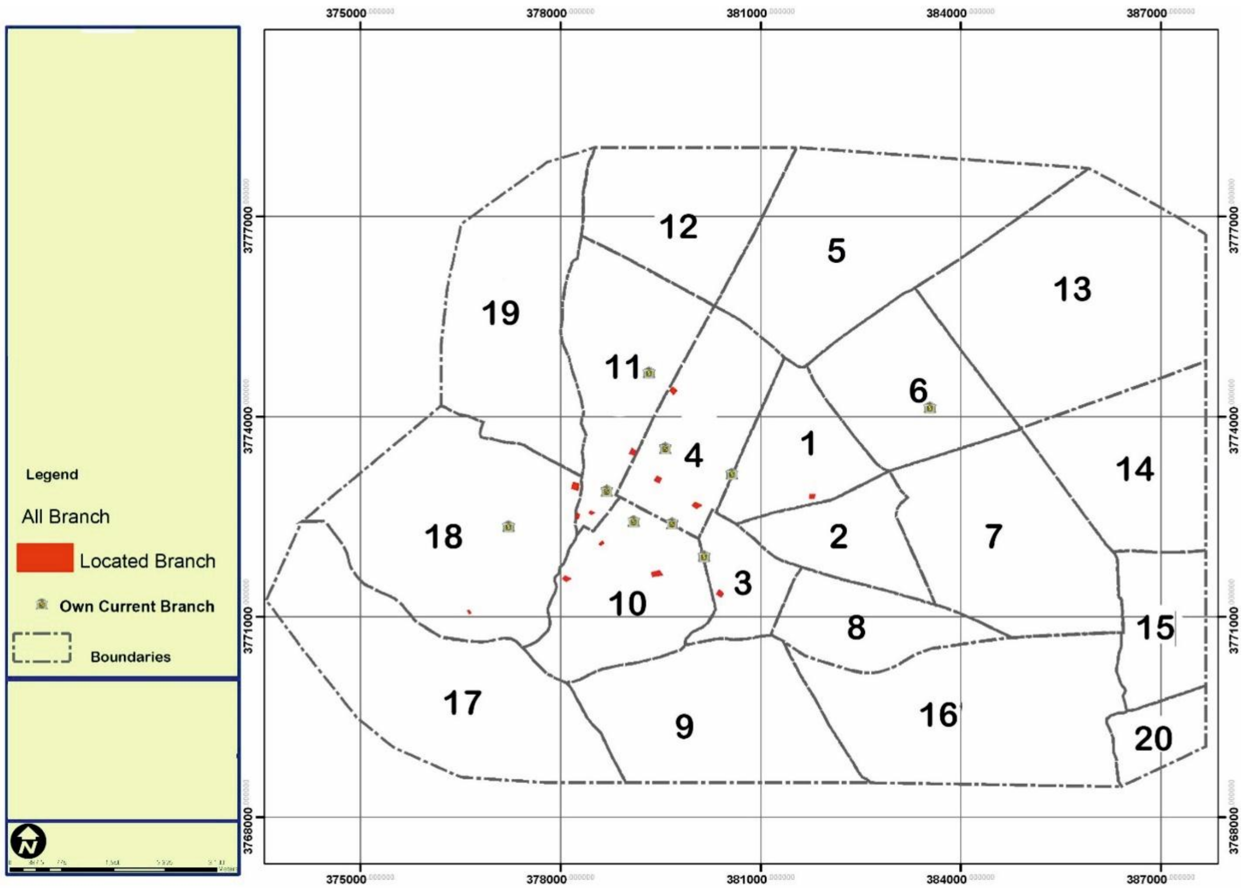

Figure ٢١. Existing and proposed branch in multiple region

٤. Conclusions and Future Research

This paper proposed integration between MCDM model represented by ANP with GIS to propose the best location for construction of a new bank branch and then using maximal covering location problem to select branches that the maximum demand might be reached within a pre-specified target travel time. The model was implemented for Mehr Eqtesad bank in Arak city, Iran. As a result, we found that the proposed model is practical and effective in identifying suitable sites with respect to multiple criteria. The model used a combination approach of operation research and GIS instead of proposing some locations empirically and ranking them with MCDM techniques.

In the future research, it is recommended to study reconstruction of bank branches. Moreover, applying this model on more complex problems is a challenging area for future studies.

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مکان یابی سایت های مناسب بر پایه GIS با پوشش حداکثری برای توسعه شعب بانک

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چکیده:
انتخاب مکان برای مکان یابی شرکت ها تصمیم بسیار مهمی است انتخاب نامناسب مکان ممکن است منجر به هزینه های بیش از حد حمل و نقل ، از دست دادن نیروی کار واجد شرایط ، مزیت رقابتی یا شرایط مشابه شود .این مقاله پیشنهاد یکپارچگی بین مدل MCDM ارائه شده توسط ANP با GIS برای پیشنهاد بهترین مکان برای ساخت یک شعبه جدید بانک و سپس استفاده از حداکثر مشکل محل پوشش برای انتخاب شعب که حداکثر تقاضا ممکن است در یک زمان از پیش تعیین شده سفر باشد.. موقعیت شعبه بانک یکی از مهمترین موضوعات استراتژیک در بازار رقابت است. در این مقاله ، یک مدل مبتنی بر سیستم اطلاعات جغرافیایی (GIS) برای مکان یابی سایت های مناسب برای ایجاد شاخه های جدید ارائه شده است ، و سپس از مسئله مکان حداکثر پوشش (MCLP) برای انتخاب شاخه ها استفاده می شود به طوری که حداکثر تقاضا در داخل زمان سفر هدف مشخص شده است. این مدل برای بانک مهر اقتصاد در شهر اراک ، ایران اجرا شد. برای تحقیقات آتی ، مطالعه بازسازی شعب بانک توصیه می شود. علاوه بر این ، استفاده از این مدل بر روی مشکلات پیچیده تر ، زمینه چالش برانگیزی برای مطالعات آینده است

.واژه های کلیدی: مکان ، سیستم اطلاعات جغرافیایی ، Esri ArcGIS برای دسک تاپ ۱۰ ، حداکثر مشکل مکان با پوشش