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A novel spatial decision support methodology to practically restructure branches network under uncertainty

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Abstract

The proper location of facilities /service providers is of paramount importance in the business success of several economy sectors for the sake of its effects on the service demand and hence on the market share. A vital problem resulted from modernization, urbanization, and globalization is the reconfiguration of branch locations and service capabilities to match the fast-changing and competitive market, regional economy, and customer distribution. This work introduces a new spatial decision support methodology to restructure branches' network with proposing a mathematical model taken from a real national project in the financial market. It considers establishing the new branches, relocating the current branches, merging the redundant branches, or ones with poor performance into the other branches. Moreover, a credibility-based fuzzy chance-constrained programming model is proposed to consider uncertainty in travel distances and market attractiveness of each node. The data and results are processed using the geographical information system (GIS) for Bank Melli in an urban district of Tehran.

Keywords: Branch restructuring problem, facility location, decision making, geographical information system, fuzzy mathematical programming.

1- Introduction

1-1- Motivation, significance and contribution

The market strategies formulated during the establishment of an organization determine that the organization is pursuing what interests in what environment. Developing and reviewing these strategies is repeated over and over throughout the life of an organization. Nowadays, advancement in technology, specifically digital technologies, has changed the world's structure and the organizations' strategies. For example, in financial institutions, despite the development of new service channels, made possible by digital technologies, the physical channel (i.e., branch) continues to maintain its position as an essential component in the combination of service channels in retail banking specifically in developing countries such as Iran.

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Case studies through the world also confirm this fact that not only do branches play an important role in the world's banks as pointed out by Temenos report (Temenos, 2019) including (1) tailored customers' experience to their unique needs and desires, (2) rich, personable face to face communication, etc., but banks have also taken steps to change and expand their branches.

The network structure of bank branches has witnessed some rising worldwide bank mergers and acquisitions, especially in the aftermath of the Great Recession from 2007 to 2009. Consequently, the number of credit institutions in the European Union from 2000 to 2008 reduced by about 22% (Fiordelisi, 2009). According to the Thomson Reuters review (Thomson Reuters, 2012), the total number of merger and acquisition transactions in 2012 was estimated two thousand in the financial sector of the European Union. The situation for some banks formed by some mergers was worse. For instance, Bank Mellat was established as the result of the merging of 10 private banks in 1979. This issue led to an oversized branch network, where some of the inherited branches were very close to each other. For this case, governmental organizing and hereditary branches caused the current network structure to be far from optimal. As stated in the book (Davis, 2000), only 20-30 percent of branch costs are likely to be saved when overlapping units are shuttered.

Generally, in facility location as a critical component of strategic planning for a broad spectrum of public and private firms, opening more branches leads to a considerable cost, but has an effect on capturing market share due to the nature of the service industries. To maintain the same service level or market share, restructuring of the current non-optimized network should be investigated by making some decisions including establishing the new branches, relocating the current branches, merging the redundant branches, or ones with poor performance into the other branches. Therefore, providing scientific solutions is necessary for such a complicated restructuring problem within an existing network which is followed by this paper as the main contribution in extending the available literature. Moreover, neglecting the uncertainty of parameters may impose high risks to firms especially for deciding at a strategic level (Qin and Ji, 2010) which is handled by this work.

1-2- Related literature

Facility location problems (FLPs) is concerned with finding the location of one or more facilities to optimize (a combination of) certain objectives such as maximizing demand coverage or market capture, minimizing total costs, maximizing service level, minimizing the time taken to deliver services, etc (Brandeau and Chiu (1989), Daskin (1995)). Although FLPs with paramount importance in the business success of the company have been studied extensively in the literature, from geography and economics to operations research and management science, not much attention has been paid to restructuring the existing network which is common after mergers and acquisitions (Ruiz-Hernández, Delgado-Gómez, and López-Pascual, 2015).

Basic questions in facility/ branch restructuring problem (BRP) are how many and which facilities are to close/ keep open/ resize/ move and which potential points are to establish new facilities due to e.g., changes in infrastructures, urban legislation, competitor's network, demand, and business relations, etc. Regarding the closure of facilities, we can refer to ReVelle, Murray and Serra (2007) and Bhaumik (2010) where additional constraints are imposed on the closure or elimination of facilities by the existing facilities and the corresponding network. On the other line, facility relocation was investigated in some works such as The Daily Review report (The Daily Review, 1998) for the automated teller machines' network of the Wells Fargo Bank. Closer to our work, Wang et al. (2003), Monteiro and Fontes (2006), and Wang et al. (2012) address simultaneously the opening and closing down of facilities.

Wang et al. (2003) presented a BRP model in response to a change in the spatial distribution of customer demand. Their model minimizes the total weighted travel distance for customers subject to a constraint on the budget for opening and/or closing facilities and a constraint on the total number of open facilities desired (Wang et al., 2003). In order to redesign a bank network in a regional framework, Monteiro and Fontes (2006) developed a non-linear restructuring model to achieve certain service levels without directly addressing the issue of branch redundancy where closing, opening, and/or relocating of the branches take into account. Wang et al. (2012) studied reconfiguration of the Industrial and Commercial Bank of China's branch locations and service capabilities to match the regional economy and customer distribution using operations research and management science approaches.

As the latest works in the field of the BRP, we can refer to the works Ruiz-Hernández, Delgado-Gómez, and López-Pascual (2015), Ruiz-Hernández and Delgado-Gómez (2016), and Yavari and Mousavi-Saleh (2019). A new capacitated BRP was proposed by Ruiz-Hernández, Delgado-Gómez, and López-Pascual, (2015) to take both closings down and long-term operations cost into consideration, and address resizing the open branches to maintain the same service level. The same authors in another work (Ruiz-Hernández and Delgado-Gómez, 2016) presented a two-stage recourse stochastic programming model to consider the uncertainty in the demand's response in BRP. Yavari and Mousavi-Saleh (2019) addressed restructuring hierarchical facilities comprising main and auxiliary in the first and second levels, respectively.

The rest of this paper is organized as follows. In section 2, we describe a new variant of the BRP with presenting the related mathematical model followed by proposing the credibility-based fuzzy chance-constrained programming model in section 3 to consider uncertainty in travel distances and market attractiveness of each node. The results of numerical experiments are reported in section 4. Finally, section 5 concludes this paper and introduces some future research directions.

2- The branch restructuring problem

This section proposes an integrated four-stage decision support methodology (figure 1) to restructure the non-optimized network of bank branches where this paper focuses on the last stage. The four stages are summarized as follows.

1. Determining the desired number of branches at the country level and the contribution of each province using econometrics and statistical methods (Eviews), e.g., statistical hypothesis testing, point and interval estimation, and different types of regression:

At the first stage, the desired number of branches at the country level is determined and the contribution of each province is assigned. To this end, using the comparative study we can select some countries that have the most similarity in terms of banking structure and financial services with the corresponding country. By analyzing the banks and their branches in terms of their attributes including the degree of development, competitiveness, size, population, gross domestic product (GDP) per capita, GDP, assets, and merger background, the desired number of branches is estimated as the interval and point estimation.

To assign the contribution of each province from the calculated overall number, we can compute the banking business potential at the provincial level. To do so, a linear polynomial model is developed based on macroeconomic indicators including the provincial GDP, the share from the annual national budget law, population, etc., and also taking into account the internal policies of the bank (both profit and non-profit) where the weight of each indicator is obtained using the expert opinions of bank managers and economic advisors.

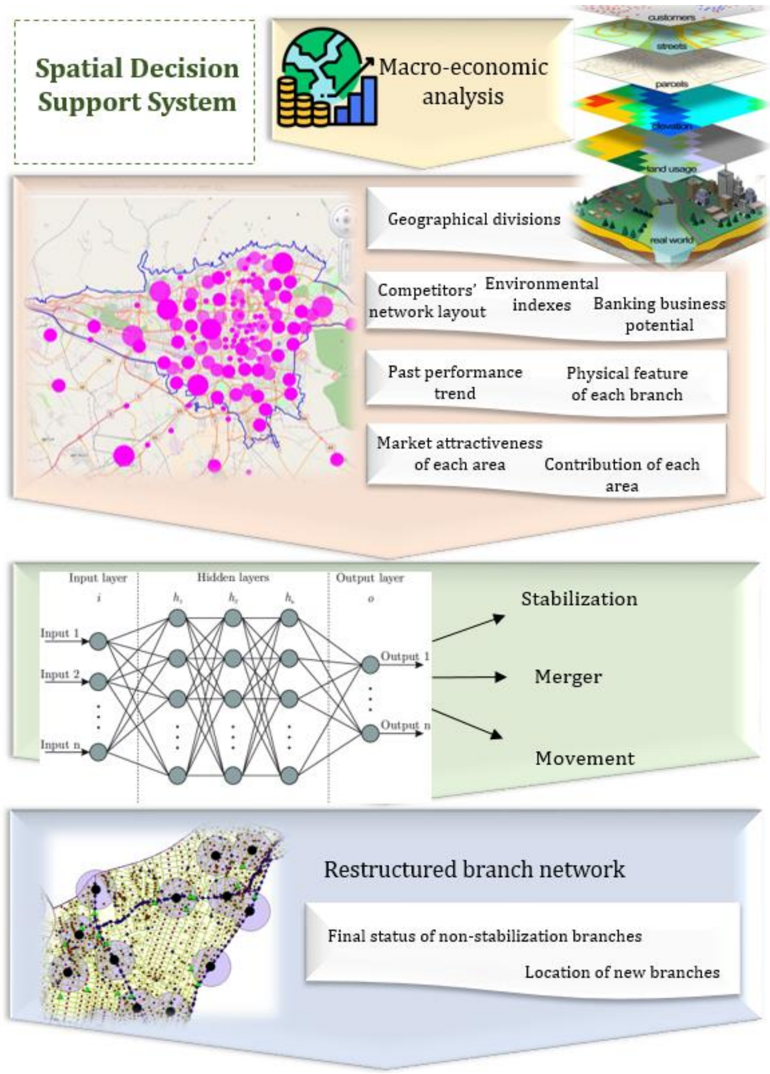

Fig 1. The conceptual model of the spatial decision support to manage the physical service delivery channels

2. Reforming the geographical divisions of each province and determining the gap between the current and desired situation of the bank branches for all divisions based on the banking business potential of each area and the performance variables of each branch using geographic information system (GIS), system dynamics (Vensim), and statistical methods (Eviews), e.g., different types of regression:

At First, the existing geographical divisions of each province such as municipal districts are reviewed to take into account some considerations including urban use (residential, commercial, etc.), geographical areas, population density, economic and cultural context, the condition of the main roads (highways, wide streets, etc.). Then, the banking business potential for each area is calculated using a non-linear polynomial model based on five main index groups including 1) demographic, 2) physical and geographical access, 3) wealth and capital, 4) income and liquidity and 5) competitors.

If the number of existing branches exceeds the capacity of each area, surplus branches should be merged or moved. If this number is commensurate with the capacity of the area, the existing branches should be stabilized or relocated within that area. For the values less than the capacity of the area, the desired solution can be the development of the branch network in that area.

3. Implementing a neural network-based expert system to determine the status of branches using MATLAB:

In this stage, the status of each branch from the viewpoint of stabilization, merger, or movement is determined using an expert spatial system based on a neural network. The structure of the neural network can be designed with two hidden and obvious layers where the obvious layer includes 9 neurons (performance, potential, network effect of branches on each other, customer classification, physical properties, etc.) and the hidden layer includes 70 neurons to perform internal computations. To train the neural network, a sample with a variety in performance index can be used. Finally, all branches are re-evaluated by the trained system to extract the final results about the situation of the branches to be stabilized, merged, or a candidate of movement.

4. Determining the restructured branch network using ILOG CPLEX Optimizer 12.3 in Microsoft visual studio:

The optimized form of the branch network is determined in this step, where this paper focuses, having the output of the previous steps, i.e., potential index of all points (current branches and candidate points), capacity of all divisions, and proposed situation of the branches. This step specifies the exact points of the branches for establishment, as well as the first and the second prioritized branch for movement candidates or for accepting the merged branches in consecutive or simultaneous mode.

In order to address the fourth stage in solving the BRP, we first describe and develop a binary linear programming mathematical model in Section 2.1 followed by the manner of obtaining the prioritized solutions in line with making the strategic decisions.

2-1- The BRP description

Suppose that a bank in a competitive market, at Step 4 in the previous section, is planning to restructure its existing network by making three decisions including establishing the new branches, relocating the current branches, merging the redundant branches or ones with poor performance into the other branches. To relocate and merge branches, options with first and second priorities are of important to find for the bank where we follow in making the related decisions. The total number of branches in each area is limited by the capacity of that area (C) resulted from Step 2 in the previous section. Given the status of each branch from Step 3, four different kinds of branch nodes are defined to model the problem, as $J = J' \cup J_4$ and $J' = J_1 \cup J_2 \cup J_3$ where the sets J_1, J_2, J_3 and J_4 represents the branch nodes to establish, the candidate branch nodes to move, the potential points to open branch, the branch nodes to merge, respectively.

Some of the important strategic considerations in restructuring branches' network in a competitive market to which our optimization problem is subject include the following concepts:

- Accessibility addressing proximity to the demand points (market),
- Vicinity addressing proximity to the competitor's nodes,
- Redundancy addressing removal of the redundant branches.

To model these strategic considerations, by defining two sets of demand points (K) and competitor's branches (N), we correspondingly introduce two following sets:

- I_k to denote the set of branches accessible to demand point $k \in K$ within a threshold distance β_1,
- I_n to denote the set of branches located within a threshold distance β_2 from the competitor's node $n \in N$.

Moreover, set I_j gives the set of branches redundant to branch $j \in J$ located within a threshold distanceβ_3. The uncertain parameters include p_j and d_{ij} denoting the market attractiveness of point $j \in J$ and the shortest network distance (by car) between two nodes i and$j$, respectively where p_j is calculated within a predefined and customized radius, similar to the banking business potential of each area defined at Step 2 in the previous section.

Before getting into the details of the mathematical formulation of the BRP, we introduce the used three binary decision variables and one continuous variable:

$y_{jj'}$	Takes value 1 if branch $j \in J_2$ is moved to point $j' \in J_3$, and 0 otherwise;
x_j	Takes value 1 if branch $j \in J$ is kept open (or is opened), and 0 otherwise;
$z_{jj'}$	Takes value 1 if branch $j \in J_4$ is merged with branch $j' \in J'$, and 0 otherwise;
r	The minimum distance between every two branches in the network;
a_k	Takes value 1 if demand point $k \in K$ is not covered within the threshold distance β_1, and 0 otherwise;
b_n	Takes value 1 if competitor $n \in N$ is not covered within the threshold distance β_2, and 0 otherwise;

Now, we present the binary linear programming mathematical model of the BRP, called *BRP model*, followed by a detailed description of the objective function and the constraints.

$$BRPmodel\text{: Max } \sum_{j \in J'} p_j . x_j \quad (1)$$
$$+w_1 . r \quad (2)$$
$$-w_2 . \sum_{i \in J_4} \sum_{j \in J'} d_{ij} . z_{ij} \quad (3)$$
$$-M \left(\sum_{k \in K} a_k + \sum_{n \in N} b_n \right) \quad (4)$$

$Subject\ to$

$$M(2 - x_j - x_{j'}) + d_{jj'} \geq r,\ \forall j \in J' \backslash J_1, \forall j' \in J' \quad (5)$$
$$x_j = 1,\ \forall j \in J_1 \quad (6)$$
$$x_j = 0,\ \forall j \in J_4 \quad (7)$$
$$\sum_{j \in I_k} x_j + a_k \geq 1,\ \forall k \in K \quad (8)$$
$$\sum_{j \in I_n} x_j + b_n \geq 1,\ \forall n \in N \quad (9)$$
$$x_j + \sum_{j' \in I_j} x_{j'} \leq 1 + RHS_j,\ \forall j \in J \quad (10)$$
$$\sum_{j \in J} x_j = C \quad (11)$$
$$\sum_{i \in J_4} z_{ij} \leq x_j,\ \forall j \in J' \quad (12)$$
$$\sum_{j \in J'} z_{ij} \geq 1,\ \forall i \in J_4 \quad (13)$$
$$(1 - x_j) = \sum_{j' \in J_3} y_{jj'},\ \forall j \in J_2 \quad (14)$$
$$\sum_{j \in J_2} y_{jj'} \leq 1,\ \forall j' \in J_3 \quad (15)$$
$$\sum_{j \in J_2} y_{jj'} \leq x_{j'},\ \forall j \in J_2, j' \in J_3 \quad (16)$$
$$y_{jj'} \in \{0,1\},\ \forall j \in J_2, j' \in J_3 \quad (17)$$
$$x_j \in \{0,1\},\ \forall j \in J \quad (18)$$

$z_{ij} \in \{0,1\}, \ \forall i \in J_4, j \in J'$ (19)

$a_k \in \{0,1\}, \ \forall k \in K$ (20)

$b_n \in \{0,1\}, \ \forall n \in N$ (21)

The objective function consists of three weighted distinct terms (1) maximizing total market attractiveness of the final branches network, (2) maximizing the minimum distance between each pair of branches, (3) minimizing the shortest network distance by car from the merging branch to its destination branch and (4) minimizing the total number of uncovered demand points and uncovered competitors within their related threshold distance penalized with big$M$. The minimum distance between two branches (r) is defined in constraints (5), where M is a large positive constant. Constraints (6) keep open the nodes to establish followed by constraints (7) to close the nodes to merge. Strategic considerations, i.e. accessibility, vicinity, and redundancy, are stated by constraints (8)-(10), respectively, where RHS_j takes value 1 if only one (or zero) member in the set I_j is the node to stable and if the number of these members is greater than 1, the value takes the numbers minus 1. Constraint (11) imposes the capacity restriction. Constraints (12) states that branch $i \in J_4$ can be merged to the point $j \in J'$ if and only if the point j is opened (or is kept open). The branch $i \in J_4$ can be merged to at most one established branch, imposed by constraints (13). Correspondingly, the constraints related to the moving branch are given by (14)-(16). Finally, constraints (17)-(21) define the three sets of binary variables.

2-2- Obtaining prioritized solutions

To obtain the first and the second prioritized branch for movement candidates and for accepting the merged branches, we act in consecutive and simultaneous mode. More precisely, the solution of the model above is identified as the first priority for movement candidates and for accepting the merged branches. By ignoring the mentioned first priority from the solution space, we can get the second priority of movement and merger in simultaneous mode. Also, by ignoring the mentioned first priority of movement without considering the priority of merger (merger without considering the priority of movement) from the solution space, we can get the second priority of movement (merger) in consecutive mode (see algorithm 1).

Input:

X = Solution of the *BRPmodel*;

Δ = Solution space defined in the *BRPmodel*.

Output:

X^1 = Second prioritized branches for movement candidates and for accepting the merged branches in simultaneous mode;

X^2 = Second prioritized branches for movement candidates without considering the priority of merger;

X^3 = Second prioritized branches for accepting the merged branches without considering the priority of movement.

X’ = First prioritized branches for movement candidates ($y_{jj'}$) in solution X;

X” = First prioritized branches for accepting the merged branches (z_{ij}) in solution X;

Δ^1 = Restricted solution space by excluding solutions X’ and X” from Δ;

Δ^2 = Restricted solution space by excluding solution X’ from Δ;

Δ^3 = Restricted solution space by excluding solution X” from Δ;

X^1 = Solution of the *BRPmodel* in solution space Δ^1;

X^2 = Solution of the *BRPmodel* in solution space Δ^2;

X^3 = Solution of the *BRPmodel* in solution space Δ^3;

Return X^1, X^2, and X3.

Algorithm 3. The framework of obtaining prioritized solutions

3- The BRP Model formulation under fuzzy travel distances

The uncertainty of input parameters can significantly affect the better modeling of real-life situations. In optimization problems, the use of fuzzy mathematical programming approaches is recommended to overcome the insufficient knowledge about data behavior and the high computational complexity of the stochastic programming models employed in most of the previous works. To cope with the uncertainty in travel distances (d_{ij}) and market attractiveness of each node (p_j), we here propose the credibility-based fuzzy chance-constrained programming model. The used method which is based upon the strong mathematical concepts, that is, the expected value of a fuzzy number and the credibility measure with a self-duality property, benefits from computationally efficient fuzzy mathematical programming approach with supporting the variants of fuzzy numbers, in addition to the adjustable chance constraints in at least some given confidence levels for the decision-maker (Pishvaee, Torabi and Razmi, 2012).

To define the credibility measure and expected value of a fuzzy variable $\tilde{\zeta}$ with membership function $\mu(x)$, we can refer to Liu and Liu (2002) as $Cr\{\tilde{\zeta} \le k\} = \frac{1}{2}(\sup_{x \le k} \mu(x) + 1 - \sup_{x > k} \mu(x))$ and therefore $E(\tilde{\zeta}) = \int_0^{\infty} Cr\{\tilde{\zeta} \ge k\}\, dk - \int_{-\infty}^{0} Cr\{\tilde{\zeta} \le k\}\, dk$ where k is a real number. Noted that the tilde (~) accent distinguishes the uncertain parameters.

Now, let $\tilde{\zeta}$ be a trapezoidal fuzzy number denoted by $\tilde{\zeta} = (\zeta_{(1)}, \zeta_{(2)}, \zeta_{(3)}, \zeta_{(4)})$. The corresponding expected value and the credibility measure are calculated as follows.

$$E(\tilde{\zeta}) = (\zeta_{(1)} + \zeta_{(2)} + \zeta_{(3)} + \zeta_{(4)})/4 \tag{22}$$

$$Cr\{\tilde{\zeta} \ge k\} = \begin{cases} 1, & k \in (\zeta_{(4)}, +\infty] \\ \frac{\zeta_{(4)} - k}{2(\zeta_{(4)} - \zeta_{(3)})}, & k \in (\zeta_{(3)}, \zeta_{(4)}] \\ \frac{1}{2}, & k \in (\zeta_{(2)}, \zeta_{(3)}] \\ \frac{2\zeta_{(2)} - \zeta_{(1)} - k}{2(\zeta_{(2)} - \zeta_{(1)})}, & k \in (\zeta_{(1)}, \zeta_{(2)}] \\ 0, & k \in (-\infty, \zeta_{(1)}] \end{cases} \tag{23}$$

$$Cr\{\tilde{\zeta} \le k\} = \begin{cases} 1, & k \in (\zeta_{(4)}, +\infty] \\ \frac{k - 2\zeta_{(3)} + \zeta_{(4)}}{2(\zeta_{(4)} - \zeta_{(3)})}, & k \in (\zeta_{(3)}, \zeta_{(4)}] \\ \frac{1}{2}, & k \in (\zeta_{(2)}, \zeta_{(3)}] \\ \frac{k - \zeta_{(1)}}{2(\zeta_{(2)} - \zeta_{(1)})}, & k \in (\zeta_{(1)}, \zeta_{(2)}] \\ 0, & k \in (-\infty, \zeta_{(1)}] \end{cases} \tag{24}$$

Accordingly, we can convert $Cr\{\tilde{\zeta} \ge k\} \ge \alpha$ to $k \le (2\alpha - 1)\zeta_{(1)} + (2 - 2\alpha)\zeta_{(2)}$ where $\alpha > 0.5$ is considered. Now, to cope with the uncertainty in travel distances (d_{ij}) and market attractiveness of each node (p_j), the proposed credibility-based fuzzy chance-constrained programming model of (25) and (26) is formulated as constraints (27) and (28).

$$Max \quad \sum_{j\in J'} E(\tilde{P}_j).x_j$$
$$+w_1.r$$
$$-w_2.\sum_{i\in J_4}\sum_{j\in J'} E(\tilde{d}_{ij}).z_{ij} \tag{25}$$
$$-M(\sum_{k\in K} a_k + \sum_{n\in N} b_n)$$

$$Cr\left(M\left(2 - x_j - x_{j'}\right) + \tilde{d}_{jj'} \geq r\right) > \alpha,\ \forall j \in J' \backslash J_1, \forall j' \in J' \tag{26}$$

$$Max \quad \sum_{j\in J'} \left(\frac{p_{j(1)}+p_{j(2)}+p_{j(3)}+p_{j(4)}}{4}\right).x_j$$
$$+w_1.r$$
$$-w_2.\sum_{i\in J_4}\sum_{j\in J'} \left(\frac{d_{ij(1)}+d_{ij(2)}+d_{ij(3)}+d_{ij(4)}}{4}\right).z_{ij} \tag{27}$$
$$-M(\sum_{k\in K} a_k + \sum_{n\in N} b_n)$$
$$M\left(2 - x_j - x_{j'}\right) + \left[(2\alpha - 1)d_{jj'(1)} + (2 - 2\alpha)d_{jj'(2)}\right] \geq r,\ \forall j \in J' \backslash J_1, \forall j' \in J' \tag{28}$$

4- Computational results

This work is a part of a real national project where the studied network has been taken from the real-world with some randomly generated data for confidentiality reasons. Suppose district 3 of Tehran urban area as a sample zone with a capacity of 27 branches for restructuring Bank Melli branches' network, depicted in Figure 2. The network consists of 36 branches of Bank Melli and 45 competitor's branches distributed in a population dividable in 1206 centroids. The accessibility distance(β_1), vicinity distance(β_2), and redundancy distance (β_3) are set to 1000m, 450m, and 350m, respectively. To determine the potential points to open branches, the main roads network is pointed every 110m in addition to some of the important points of local roads, resulted in 774 points. Euclidean distance is used to calculate the distance d_{ij} between two nodes i and$j$. Values of the two weightsw_1, w_2 are considered 15 and 2, respectively. The market attractiveness of each branch node ($p_j, j \in J_1 \cup J_2 \cup J_4$) and potential node ($p_j, j \in J_3$) are generated as float values uniformly distributed in [120, 200] and [100, 200] ([100, 160] for the points on the local roads and not main roads). Moreover, the status of each Bank Melli branch is randomly assigned to stabilization, movement, and merger. Finally, the four prominent values used to the trapezoidal fuzzy numbers of the two uncertain parameters $\tilde{p}$ and $\tilde{d}$ are determined at 0.7, 0.85, 1.15, 1.3 of the nominal value of each parameter. It is noted that the four values in each cell of the following tables report the prioritized solutions according to the same order which were described in section 2.2.

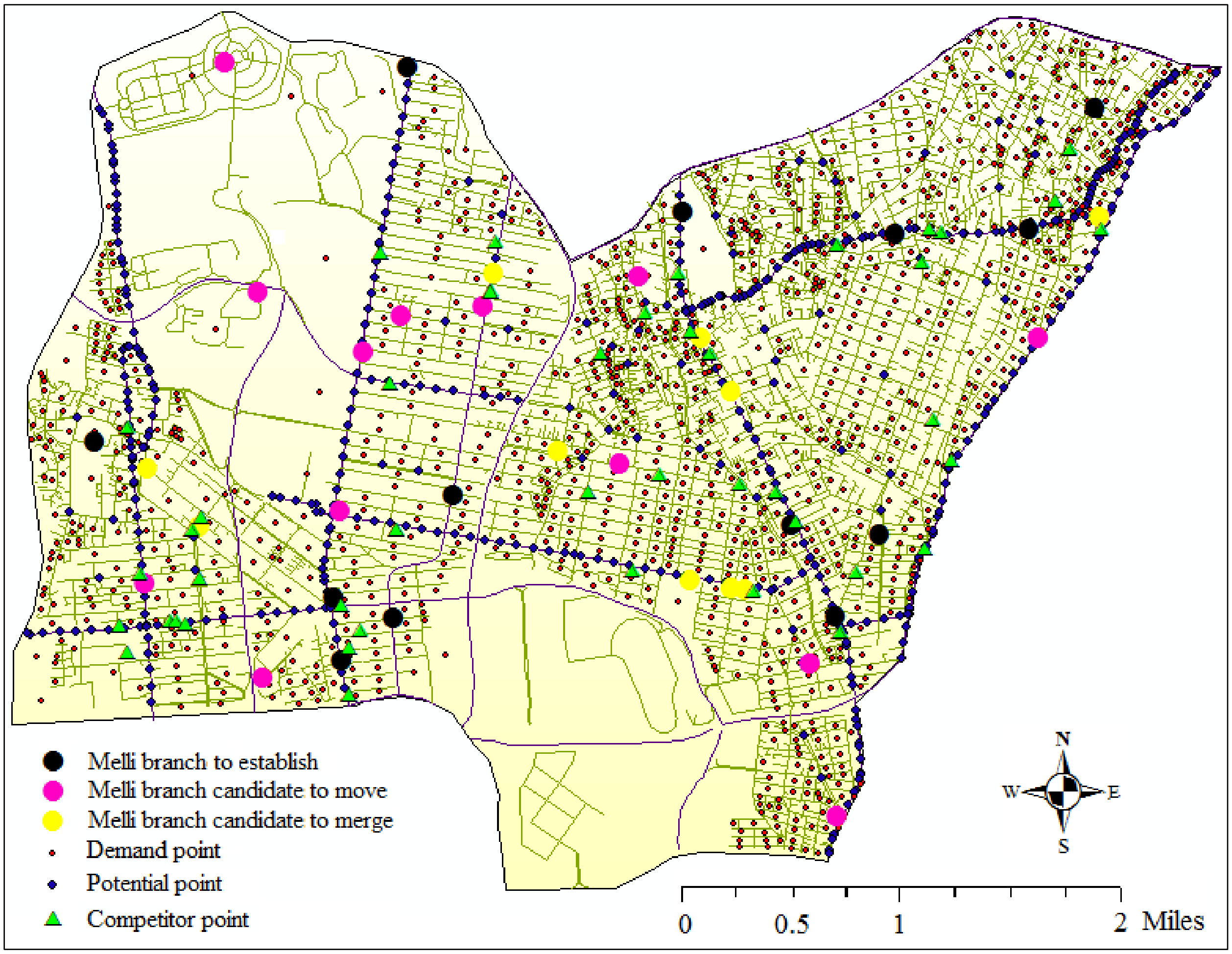

Fig 2. District 3 of Tehran municipality area

Now, we perform a sensitivity analysis to obtain a better understanding of the effect of the most effective parameters of the model on the three terms of the objective function and the prioritized solutions as explained at the end of section 2. The first sensitivity analysis is conducted on the district capacity for three alternative values including 27, 31, and 36 which is reported in Table 1. For the three capacity values 27, the restructured network are shown in figure 3, 4 and 5 where each node has been surrounded by a buffer of 350m (β_3).

Table 1. Sensitivity analysis for changes in district capacity

	Capacity value		
Solution value	27	31	36
$\sum_{j\in J'} p_j . x_j$	4837.0, 4786.0, 4837.0, 4786.0	5462.0, 5473.0, 5462.0, 5473.0	6435.0, 6446.0, 6435.0, 6446.0
$\sum_{i\in J_4}\sum_{j\in J'} d_{ij} . z_{ij}$	3025.6, 4064.4, 3025.6, 4064.4	2533.9, 3060.0, 2533.9, 3060.0	2533.9, 3060.1, 2533.9, 3060.1
r	484.1, 484.3, 484.1, 484.3	484.1, 484.3, 484.1, 484.3	484.1, 484.3, 484.1, 484.3
$\sum_{k\in K} a_k$	0, 0, 0, 0	0, 0, 0, 0	0, 0, 0, 0
$\sum_{n\in N} b_n$	0, 0, 0, 0	0, 0, 0, 0	0, 0, 0, 0

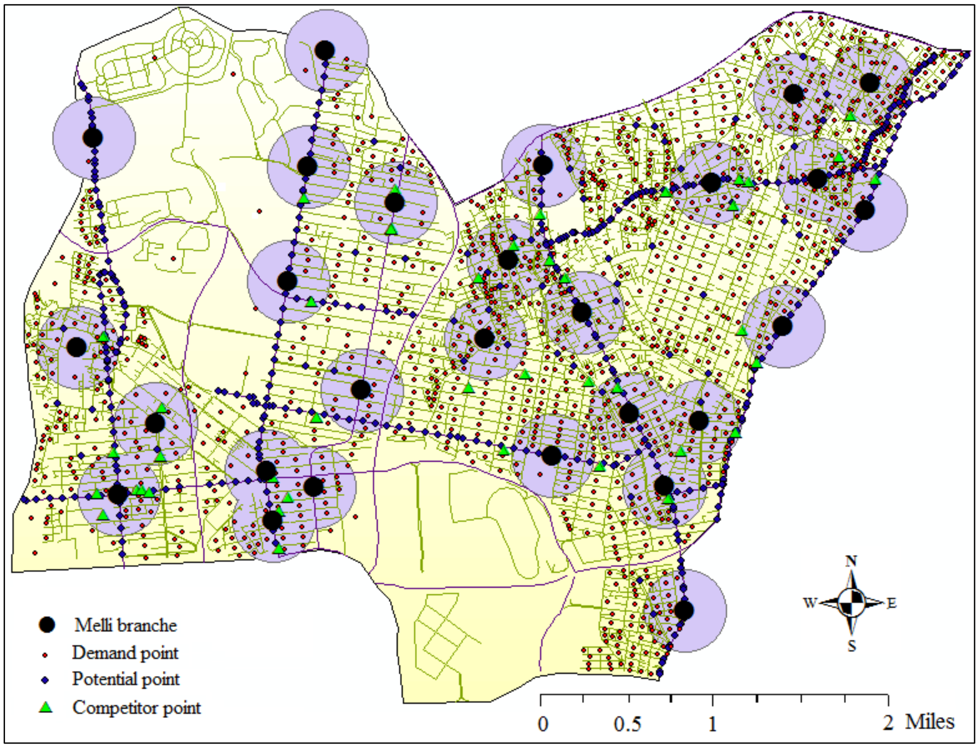

Fig 3. The restructured branch network of district 3 of Tehran municipality area under capacity 27

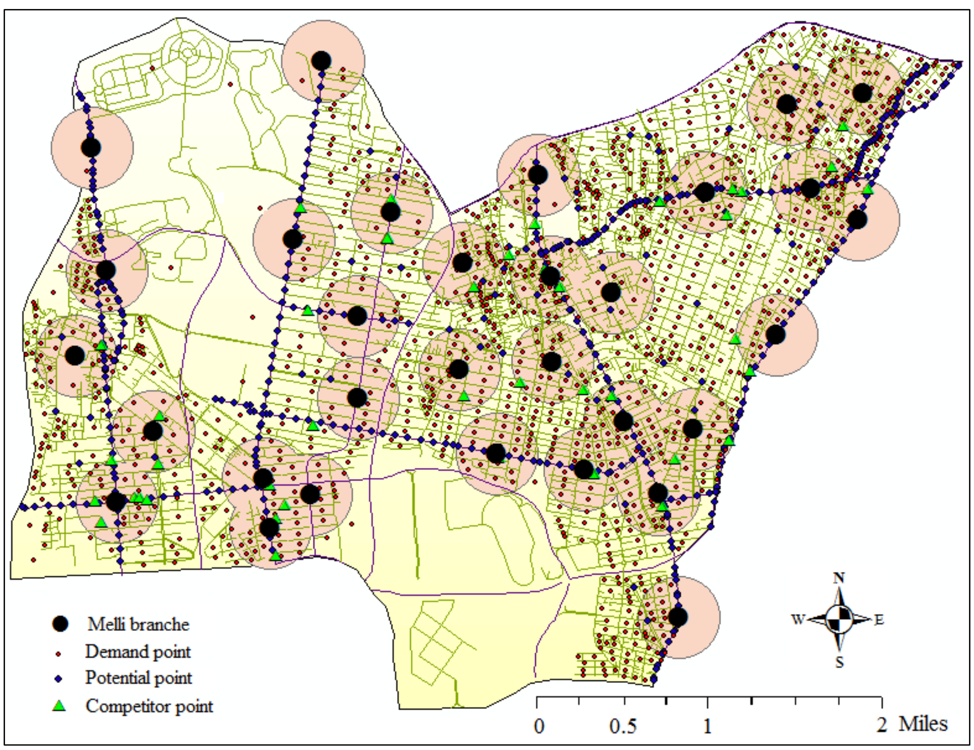

Fig 4. The restructured branch network of district 3 of Tehran municipality area under capacity 31

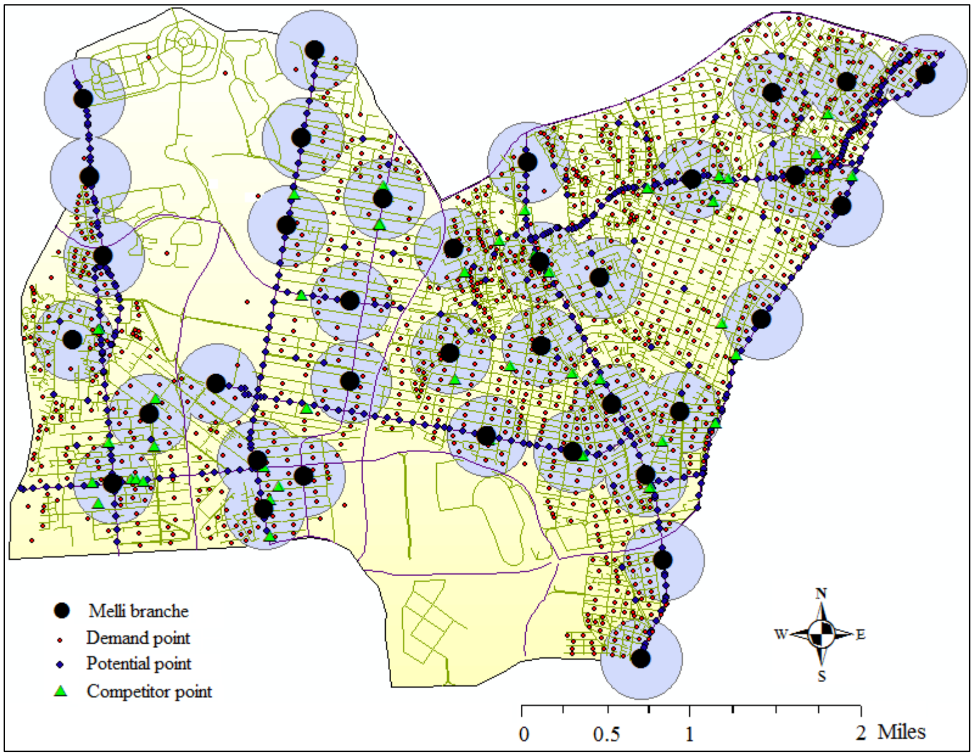

Fig 5. The restructured branch network of district 3 of Tehran municipality area under capacity 36

Another sensitivity analysis has been performed on distance parameters, i.e.,β_1 β_2 andβ_3, for three alternative values including (800, 1000, 1200), (300,450,600) and (250,350,450), respectively (see table 2).

Table 2. Sensitivity analysis for changes in distance parametersβ_1, β_2 andβ_3

$\beta_2 = 300$		β_1		
β_3	**Solution value**	**800**	**1000**	**1200**
250	$\sum_{j\in J'} p_j . x_j$	4769.0, 4641.0, 4769.0, 4641.0	4822.0, 4789.0, 4824.0, 4829.0	4810.0, 4828.0, 4845.0, 4826.0
	$\sum_{i\in J_4}\sum_{j\in J'} d_{ij} . z_{ij}$	3167.7, 5144.6, 3167.7, 5144.6	2600.1, 4223.6, 2348.6, 4837.5	2292.2, 3319.1, 2040.6, 3911.0
	r	561.9, 561.9, 561.9, 561.9	501.8, 501.8, 501.8, 501.8	548.5, 528.5, 548.5, 528.5
	$\sum_{k\in K} a_k$	4, 5, 4, 5	0, 0, 0, 0	0, 0, 0, 0
	$\sum_{n\in N} b_n$	10, 9, 10, 9	7, 8, 8, 7	7, 8, 8, 7
350	$\sum_{j\in J'} p_j . x_j$	4710.0, 4636.0, 4696.0, 4636.0	4724.0, 4712.0, 4726.0, 4710.0	4788.0, 4752.0, 4790.0, 4750
	$\sum_{i\in J_4}\sum_{j\in J'} d_{ij} . z_{ij}$	3056.8, 4973.9, 3056.8, 4973.9	3152.1, 5251.2, 2900.5, 5843.1	3247.7, 4605.0, 2996.1, 5196.9
	r	538.3, 552.7, 538.3, 552.7	387.4, 387.4, 387.4, 387.4	552.7, 484.3, 552.7, 484.3
	$\sum_{k\in K} a_k$	3, 5, 4, 5	0, 0, 0, 0	0, 0, 0, 0
	$\sum_{n\in N} b_n$	12, 10, 11, 10	7, 8, 8, 7	7, 8, 8, 7
450	$\sum_{j\in J'} p_j . x_j$	4643.0, 4555.0, 4643.0, 4555.0	4738.0, 4685.0, 4740.0, 4703.0	4812.0, 4765.0, 4783.0, 4725.0
	$\sum_{i\in J_4}\sum_{j\in J'} d_{ij} . z_{ij}$	3393.1, 5702.7, 3393.1, 5702.7	3718.9, 5438.9, 3467.3, 5921.5	3887.3, 5601.7, 3467.3, 5921.5
	r	510.5, 510.5, 510.5, 510.5	580.4, 521.8, 580.4, 580.4	750.0, 750.0, 710.7, 730.2
	$\sum_{k\in K} a_k$	8, 9, 8, 9	0, 0, 0, 0	0, 0, 0, 0
	$\sum_{n\in N} b_n$	15, 14, 15, 14	13, 14, 14, 13	13, 14, 14, 13

Table 2. Continued

$\beta_2 = 450$		β_1		
β_3	Solution value	800	1000	1200
250	$\sum_{j\in J'} p_j . x_j$	4784.0, 4807.0, 4823.0, 4758.0	4880.0, 4821.0, 4880.0, 4821.0	infeasible
	$\sum_{i\in J_4} \sum_{j\in J'} d_{ij} . z_{ij}$	3276.9, 4834.8, 3276.9, 5798.9	2765.1, 3665.4, 2765.1, 3665.4	-
	r	656.9, 581.2, 656.9, 656.9	581.2, 581.2, 581.2, 581.2	-
	$\sum_{k\in K} a_k$	3, 5, 4, 2	0, 0, 0, 0	-
	$\sum_{n\in N} b_n$	2, 1, 2, 3	0, 0, 0, 0	-
350	$\sum_{j\in J'} p_j . x_j$	4648.0, 4817.0, 4829.0, 4758.0	4837.0, 4786.0, 4837.0, 4786.0	4880.0, 4813.0, 4880.0, 4813.0
	$\sum_{i\in J_4} \sum_{j\in J'} d_{ij} . z_{ij}$	3321.8, 5467.2, 3276.9, 5754.0	3025.6, 4064.4, 3025.6, 4064.4	2822.4, 3562.3, 2822.4, 3562.3
	r	656.9, 656.9, 656.9, 656.9	484.1, 484.3, 484.1, 484.3	484.1, 484.3, 484.1, 484.3
	$\sum_{k\in K} a_k$	3, 4, 4, 2	0, 0, 0, 0	0, 0, 0, 0
	$\sum_{n\in N} b_n$	2, 2, 2, 3	0, 0, 0, 0	0, 0, 0, 0
450	$\sum_{j\in J'} p_j . x_j$	4767.0, 4642.0, 4767.0, 4682.0	4850.0, 4683.0, 4766.0, 4683.0	4912.0, 4742.0, 4906.0, 4816.0
	$\sum_{i\in J_4} \sum_{j\in J'} d_{ij} . z_{ij}$	3276.9, 6084.0, 3276.9, 5916.2	3425.5, 4784.2, 3477.8, 4784.2	3425.5, 5017.7, 3543.3, 4849.7
	r	580.4, 580.4, 580.4, 580.4	580.4, 580.4, 580.4, 580.4	750.2, 732.7, 732.7, 705.6
	$\sum_{k\in K} a_k$	8, 8, 8, 8	0, 0, 0, 0	0, 0, 0, 0
	$\sum_{n\in N} b_n$	2, 2, 2, 2	1, 1, 1, 1	1, 1, 1, 1
$\beta_2 = 600$		β_1		
β_3	Solution value	800	1000	1200
250	$\sum_{j\in J'} p_j . x_j$	4841.0, 4761.0, 4881.0, 4721.0	infeasible	infeasible
	$\sum_{i\in J_4} \sum_{j\in J'} d_{ij} . z_{ij}$	3344.5, 4851.8, 3344.5, 4851.8	-	-
	r	637.5, 656.9, 637.5, 656.9	-	-
	$\sum_{k\in K} a_k$	2, 3, 3, 2	-	-
	$\sum_{n\in N} b_n$	0, 0, 0, 0	-	-
350	$\sum_{j\in J'} p_j . x_j$	4799.0, 4767.0, 4839.0, 4727.0	4881.0, 4807.0, 4881.0, 4807.0	4956.0, 4885.0, 4956.0, 4953.0
	$\sum_{i\in J_4} \sum_{j\in J'} d_{ij} . z_{ij}$	3502.5, 4523.2, 3502.5, 4523.2	2845.4, 3966.7, 2845.4, 3966.7	3140.1, 4198.0, 3140.1, 4054.2
	r	656.9, 656.9, 656.9, 656.9	656.9, 656.9, 656.9, 656.9	839.3, 770.6, 839.3, 730.9
	$\sum_{k\in K} a_k$	2, 3, 3, 2	0, 0, 0, 0	0, 0, 0, 0
	$\sum_{n\in N} b_n$	0, 0, 0, 0	0, 0, 0, 0	0, 0, 0, 0
450	$\sum_{j\in J'} p_j . x_j$	4756.0, 4760.0, 4795.0, 4695.0	4870.0, 4692.0, 4870.0, 4692.0	4816.0, 4921.0, 4863.0, 4921.0
	$\sum_{i\in J_4} \sum_{j\in J'} d_{ij} . z_{ij}$	3207.4, 5357.8, 3207.4, 5357.8	3136.6, 4714.7, 3136.6, 4714.7	3393.1, 5108.1, 3284.5, 5108.1
	r	580.4, 580.4, 580.4, 580.4	580.4, 580.4, 580.4, 580.4	857.1, 839.3, 839.3, 839.3
	$\sum_{k\in K} a_k$	7, 8, 8, 7	0, 0, 0, 0	0, 0, 0, 0
	$\sum_{n\in N} b_n$	0, 0, 0, 0	0, 0, 0, 0	0, 0, 0, 0

Here, we present the detailed results obtained for three different uncertainty levelα. Table 3 shows that r decreases with a higher uncertainty level.

Table 3. Analysis of the uncertainty level

	Uncertainty level α		
Solution value	**0.6**	**0.8**	**1.0**
$\sum_{j\in J'} p_j.x_j$	4837.0, 4786.0, 4837.0, 4786.0	4837.0, 4786.0, 4837.0, 4786.0	4837.0, 4786.0, 4837.0, 4786.0
$\sum_{i\in J_4}\sum_{j\in J'} d_{ij}.z_{ij}$	3025.6, 4064.4, 3025.6, 4064.4	3025.6, 4064.4, 3025.6, 4064.4	3025.6, 4064.4, 3025.6, 4064.4
r	397.0, 397.1, 397.0, 397.1	367.9, 368.1, 367.9, 368.1	338.9, 339.0, 338.9, 339.0
$\sum_{k\in K} a_k$	0, 0, 0, 0	0, 0, 0, 0	0, 0, 0, 0
$\sum_{n\in N} b_n$	0, 0, 0, 0	0, 0, 0, 0	0, 0, 0, 0

5- Conclusions

In this work as a summary of a real national project, we have proposed a new variant of the BRP within a spatial decision support methodology. It addresses the problem of establishing the new branches, relocating the current branches, merging the redundant branches, or ones with poor performance into the other branches. The data and results are processed using the geographical information system (GIS) for Bank Melli in an urban district of Tehran. Although our work has been motivated by the banking sector in the financial market, it can be simply adapted to other business sectors of the economy. From a business viewpoint, the application of our BRP variant will empower a more efficient allocation of service providers /resources by taking advantage of economies of location and scale.

One extension of our proposed model may be to consider the main and auxiliary facility to cover each demand point within different coverage radiuses (β_1). Another extension could be incorporating the hierarchical services.

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