

A Solution Approach for Agricultural Service Center Location Problem Using TOPSIS, DEA and SAW Techniques

Morteza Zangeneh, Asadolah Akram, Peter Nielsen, Alireza Keyhani and Narges Banaeian

Abstract In this research, agricultural service centers have been introduced as a strategic decision to improve efficiency of agricultural supply chain. Since the location problems in agriculture exhibit several features, such as their large scope and size, and demonstrate increased levels of complexity, so the main aim of this study is developing an integrated Multi-Attribute Decision Making (MADM) approach considering all aspects of the Agricultural Service Center Location Problem (ASCLP) including: customers, service suppliers, and also technical suitability of candidate location. In this regard two main MADM approaches are developed. The first approach was the combination of Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Data Envelopment Analysis (DEA). The second approach is developed to improve the solutions for some cases which the first approach was unable to reach to the non-dominated solutions. Before completing the MADM approaches, initially a Delphi fuzzy-analytical hierarchy process survey has been completed to extract the objectives and attributes of ASCLP and their local weight, which is published in previous work by the authors. The main contribution of current chapter is to consider more comprehensively the attributes in solving a service facility location problem such as: distances to demand points and also suppliers, cultivated area of demand points, population of demand points, number of cultivated crops, and the ration of irrigated cultivated lands to dried cultivated lands. The developed approach was able to use all mentioned decision methods, simultaneously. In the second approach, the developed attributes are used, two scores

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(maxi-min and maxi-max) for each candidate location is computed and non-dominated solutions are identified. To prove the capability of the selected attributes one case study is addressed. The results reveal that the chosen attributes to a very large degree can lead to the non-dominated solutions.

Keywords Supply chain • Agriculture • Service • Location • Decision making

1 Introduction

Agriculture is the only main sector which uses the land surface as an essential input into its production function. This wide geographical dispersion of agricultural commodities has an important economic consequence; transportation becomes essential to leave the outputs from the farm for consumption by others or if inputs are to be used on the farm to increase output (Timmer et al. 1983).

In supply chain design, locating and sizing facilities to serve customers is a critical part which presents a number of challenges. Customers are sensitive to the total cost of interacting with a firm's service, including time and access cost, in addition to price (Pangburn and Stavroulaki 2005). Lucas and Chhajed (2004) use a number of distinguishing features to identify location problems in agriculture. They believe that many agricultural location studies took place in developing countries, and most of these studies were initiated upon request of a government agency, because in developing areas, agriculture is a key sector: it provides food, stimulates foreign exchange earnings, and generates a large share of a country's total employment. The location problems in agriculture exhibit several features, such as their large scope and size, variation in time of different operations in agriculture in different areas, yield and quality variation of a given commodity due to inter-regional disparities in climate, or the consideration of multiple and often conflicting objectives such as: maximize a profit function, minimize cost; distance or time; number of facilities, government expectations from agricultural sector and its policies and, thus, demonstrate increased levels of complexity (Lucas and Chhajed 2004).

1.1 Agricultural Services

Several services can be given to the whole of agricultural supply chain. Some services are for farms, specifically. In the following section four types including: input supply, mechanization services, advisory services and financial services are discussed.

The majority of farm input supply companies are concentrated in urban areas or rural zones with large concentrations of commercial farmers. Therefore millions of poor farmers in rural areas without large commercial farmers do not have access to affordable agricultural inputs such as improved seeds, chemical fertilizers and other agro chemicals needed to help them raise their farm productivity

(Dorward and Chirwa 2011). So the location of agricultural input suppliers must be close to the farms to accelerate the input supply for them.

Agricultural mechanization includes the use of tools, implements and machines for agricultural land development, crop production, harvesting, and preparation for storage, storage, and on-farm processing. The manufacture, distribution, repair, maintenance, management and utilization of agricultural tools, implements and machines is covered under this discipline with regard as to how to supply mechanization inputs to the farmer in an efficient and effective manner. (Lak and Almasi 2011). This service type needs to be near to the farms, because of high transportation cost for agricultural machinery from service provider to customer's farm.

The basic indicators for success of a demand-driven advisory service system in agriculture are: farmers have access to agricultural advisory services, farmers use the advisory services, farmers have increased income from agricultural production, and finally greater choice and competition among agricultural advisers. The particular objective of supporting agricultural advisory services to the farms is to improve the agricultural income and productivity consequently (Chipeta 2006).

The limited access to financial resources may lead to several problems in agricultural production such as: disturb the time of farming operations (input supply, planting, trading and etc.), decrease the input quality and etc. So increase the access to financial services including loan and insurance can improve the productivity in agriculture.

Agricultural facilities may have different topological structures. Bojic et al. (2013) suggest an allocation model to solve biomass power plant locations. Their model was created from nodes and arcs (network structure). The nodes represent primary storages and potential power plant locations. The arcs represent the existing transport connections between the nodes. An example of discrete topological structure is Thompson et al. (2013) which use Geographical Information System (GIS) analysis to create and map a data layer of polygons that indicate all of the potential locations where, based on suitability criteria, anaerobic digester system can be installed.

Location analysis in planning for regional development can provide a framework for investigating service accessibility problems, analyzing previous locational decisions and generating alternatives to suggest more efficient service systems (Farrow et al. 2011). Many studies have used this concept for public health facilities (Teixeira and Antunes 2006), but few studies have been done in solving problems of input firms in the agricultural context (Farrow et al. 2011). Poor physical accessibility to both private and public sector retailers increases costs for farmers. So it is necessary to pinpoint underserved areas and identify optimal sites for locating new agro-dealers (Farrow et al. 2011).

1.2 Multi-attribute Decision Making in Location Problem

The distinguishing feature of the MADM problems is that there are usually a limited number of predetermined alternatives. These alternatives satisfy each objective in a specified level. There are many techniques, which are used to solve the

MADM problems. The most relevant techniques are: dominant, maxi-min, maxi-max, conjunctive method, disjunctive methods, lexicographic method, elimination by aspects, permutation method, Simple Additive Weighting (SAW), hierarchical additive weighting, Elimination and Choice Expressing Reality (ELECTRE), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Linear programming Techniques for Multidimensional Analysis of Preference (LINMAP) and etc. (Hwang and Yoon 1981). Some other MADM methods have been successfully used in various location problems in literatures such as Analytic Network Process (ANP), Analytic Hierarchy Process (AHP), Multi-Attribute Utility Theory (MAUT), and Stochastic Multi-criteria Acceptability Analysis (SMAA) (Aras et al. 2004; Higgs 2006; Tuzkaya et al. 2008).

1.3 Agricultural Service Center Location Problem

Improving efficiency is the key parameter of any system to be sustainable and successful. A strategy has been developed by Iranian agricultural ministry to create a network of agricultural service firms. In this study a new framework for specifying the service center location is developed. Agricultural services have different characteristics in comparison with other public services such as health, police or etc. These characteristics make their location selection procedure somehow different. Some assumptions have been considered in current location problems regarding customers (see Table 1). There are three types of customers in this location problem, which their characteristics explained in following section:

Customer type A: The number of farms is very large, and is hard to consider all of them; so this study will aggregate the all demand of each village in the center of that village. Also the demand weight of all farms will be sum up as demand of village point (these aggregated points will be called as demand point in this study). Any demand point has different type of service requirements and may need several services in several times. Candidate locations and demand points are the same (both are the village points). For transport any product of each demand point, it's enough to reach the demand point and the destination is not important in this location problem.

Customer type B and C: they want to access the services on their location. There may be customers of these types or not.

The layout of location problem of agricultural service centers (ASC) can be seen in Fig. 1. Since there are several services, more distance functions should be considered.

Initially a Delphi fuzzy-AHP survey has been done to extract the objectives and attributes of the ASCLP. Subsequently using Fuzzy Analytic Hierarchy Process (FAHP) the local weight of location attributes for the location problem is computed (Zangeneh et al. 2014). The main aim of current study is developing a multi-attribute decision making approach to consider all aspects of the ASCLP for customer type A (the most popular customer of ASC). The ideal solution for

Table 1 Services description

Characteristics	Service type		Post production			
	Pre-production	Production	Consulting for farms	Financial	Consulting	Inspection
Times for each season	Input supply	Mechanization	Multiple	Single	Multiple	Single
Customer for each service	Single	Multiple	Multiple	Single	Multiple	Multiple
Location of service demand	A, B, C	A	A	A	B, C	A, B, C
Capacity	On farm	On farm	On service center	On service center	On site	On site
Demand weight	Unlimited	Limited	Unlimited	Limited	Unlimited	Limited
Time criticality	Weighted	Weighted	Un-weighted	Weighted	Un-weighted	Weighted
	Yes	Yes	No	Yes	No	Yes

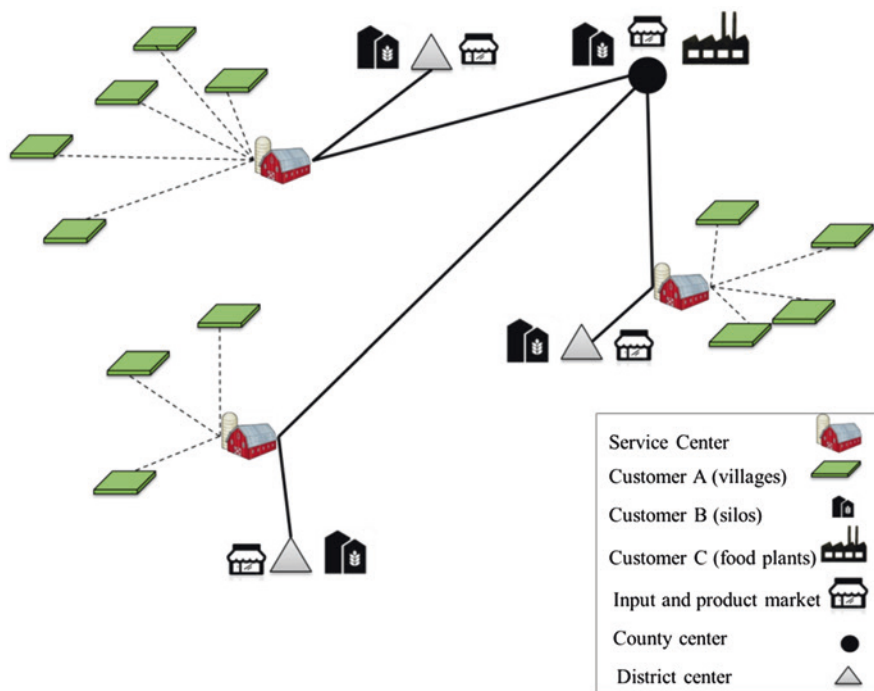


Fig. 1 Layout of the studied service network

this location problem should satisfy the main objectives of this research including: maximize service quality, service speed, and service centers profit and minimize service cost simultaneously.

2 The Method

In this chapter the concept of MADM method is applied to get best candidate locations for agricultural service centers in rural regions. The general procedure to develop the integrated MADM approach has been shown in Fig. 2.

At first the main objective of establishing ASC defined using Delphi method (Zangeneh et al. 2014). Then, based on the ASC objectives and inherent characteristics of agricultural services, the location problem of ASC defined. There are two main methods to solve the ASC location problem, but the solution space determines the appropriate method. In this study discrete solution space considered, so MADM method will be applied. In continuous solution space, if isn't possible to gain the required data for whole of the solution space, a substitute way is to reduce the solution space to a discrete one and then apply the MADM methodology.

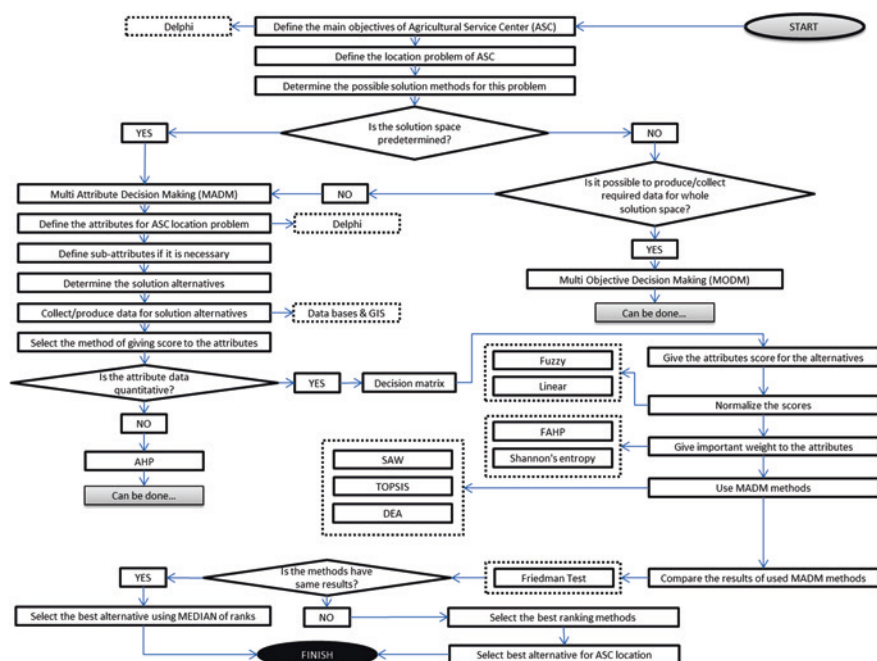


Fig. 2 The procedure of MADM method

First action in MADM is specifying attributes and also sub-attributes if it is necessary. In this phase, Delphi method can be used to help. The sub-attribute definition is to facilitate the data gathering. The data must be gathered or generated from databases, surveys and Geographical Information System (GIS) and etc. Next step is the giving score to the attributes for each alternative (candidate location). In this step, according to attribute data type, quantitative or qualitative, decision matrix method or AHP can be selected. In the current study, because of several technical reasons, village points are proposed as candidate location in each region. Quantitative data more than qualitative data will lead to reliable judgment about candidate locations. So in this study qualitative data is preferred and decision matrix method is selected for giving score to the attributes of candidate locations.

Some decision methods such as SAW and TOPSIS use the additive values of attributes to analysis. Since the type of data is different for all attributes, data normalization is required. Some other ranking methods, such as DEA, are not sensitive to the unit of data, but in this study normalized data is used for all analysis. In this research fuzzy and linear normalization methods are used. The data order in the linear normalization method is retained, while in the fuzzy normalization method the order is disturbed. Totally in this chapter seven MADM methods are applied and because of the linear normalization method ability, in this research linear method is used in five methods.

2.1 Linear Normalization Method

Simple linear normalization method is used. For both positive and negative attributes separate formulations have been used. Equations 1 and 2 have been used for positive and negative attributes, respectively (Shakouri et al. 2014):

$$Z_{ij} = \frac{a_{ij}}{\max(a_{ij})} \quad (1)$$

$$Z_{ij} = \frac{\frac{1}{a_{ij}}}{\max(\frac{1}{a_{ij}})} \quad (2)$$

2.2 Fuzzy Normalization Method

The fuzzy normalization formula for positive attributes and negative attributes are describes in Eqs. 3 and 4, respectively:

$$z_{ij} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}} \quad (3)$$

$$z_{ij} = \frac{\max a_{ij} - a_{ij}}{\max a_{ij} - \min a_{ij}} \quad (4)$$

Usually the relative importance of attributes is different, so a weighting method for attributes must be applied. In this study, two relevant methods has been used; FAHP and Shannon's entropy.

2.3 Fuzzy-AHP

The procedure of standard FAHP has been fully described in Zangeneh et al. (2014).

2.4 Shannon's Entropy

The original Shannon's entropy comes with the concept of information theory, where it is used to measure uncertainty expressed by distribution of p_i , and find how much storage is needed to capture all uncertain information. The calculations can be expressed in a series of formulas that are expressed below (Shakouri et al. 2014):

$$E_j = -k \sum_{i=1}^n [P_{ij} \times \ln (P_{ij})] \quad \forall j \quad (5)$$

where, each P_{ij} is calculated as an estimate of the probability distribution for the attributes by:

$$P_{ij} = \frac{z_{ij}}{\sum_{i=1}^n z_{ij}} \quad \forall i, j \quad (6)$$

And k is a constant coefficient equal to:

$$k = \frac{1}{\ln(n)} \quad (7)$$

Uncertainty or degree of deviation of the data for index j , namely d_j , states how much information each of the criterion indexed by j contains for decision making, i.e. how much information it is. This value is obtained simple as:

$$d_j = 1 - E_j \quad \forall j \quad (8)$$

Then, the weight of each criterion is calculated by:

$$w_j = \frac{d_j}{\sum_{i=1}^n d_j} \quad \forall j \quad (9)$$

Next step is MADM method development. In this chapter, totally seven MADM method applied to find best location for ASC. In this section, six MADM methods are described. The methods are different combination of SAW, TOPSIS and DEA. The characteristics of these methods are illustrated in Fig. 3.

2.5 TOPSIS Technique

TOPSIS is a multiple criteria decision making method which is initially developed by Hwang and Yoon (1981). The technique is based on the idea that the

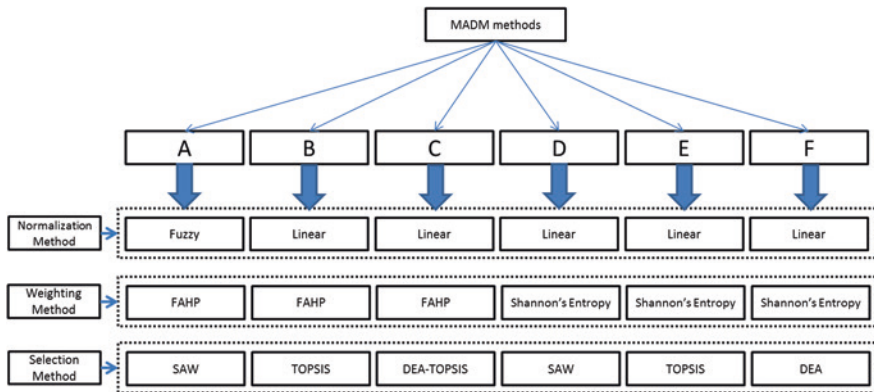


Fig. 3 The characteristics of integrated MADM methods

optimal solution should have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution (Oztaysi 2014). In current research, the maximum value of each attribute is considered as positive ideal solution and the minimum value as negative ideal solution. This values is mentioned for positive attributes where higher value of them are preferred for the location of ASC, e.g. population of candidate location, while for negative attributes is vice versa. To determine these values, the decision matrix is formed and normalized by using the linear method. Then the positive ideal solution (A^+) and negative ideal solution (A^-) is determined as described in Roy (2004).

After calculating the ideal solutions, the distances of each alternative to the A^+ and A^- calculated as R^+ and R^- , respectively (see Eqs. 10 and 11) (Oztaysi 2014):

$$R_j^+ = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^+)^2} \quad i = 1, 2, \dots, J \quad (10)$$

$$R_j^- = \sqrt{\sum_{j=1}^m (v_{ij} - v_j^-)^2} \quad i = 1, 2, \dots, J \quad (11)$$

where; v_j^+ is the positive ideal and v_j^- is the negative ideal for the criteria j .

Using these calculated values closeness index (C.I.) for each alternative is computed using Eq. 12 (Roy 2004):

$$C.I. = \frac{(R^-)}{(R^+) + (R^-)} \quad (12)$$

The closeness index can get values between 0 and 1 and the alternative which has the highest $C.I.$ is selected as the best alternative (Oztaysi 2014).

2.6 DEA Technique

DEA first introduced by Charnes, Cooper, and Rhodes (CCR) (Charnes et al. 1978). The original CCR model was applicable only to technologies characterized by constant returns to scale (CRS) globally. Banker et al. (1984) divide the overall efficiency into technical and scale efficiencies. Technical efficiency is defined as the Decision Making Unit (DMU's) ability to achieve maximum output from given inputs. Using standard notations, the efficiency can be written as Eq. 13 (Charnes et al. 1978):

$$Efficiency = \frac{u_1 y_1^{j^*} + u_2 y_2^{j^*} + \dots + u_N y_N^{j^*}}{v_1 x_1^{j^*} + v_2 x_2^{j^*} + \dots + v_M x_M^{j^*}} \quad (13)$$

where, $u_1, u_2, \dots$ are the weight given to output n ($n = 1, 2, \dots, N$); $y_1^{j^*}, y_2^{j^*}, \dots, y_N^{j^*}$ are the amount of output n of Decision Making Unit (DMU) j^* ; $v_1, v_2, \dots$ are the weight given to input m ($m = 1, 2, \dots, M$); $x_1^{j^*}, x_2^{j^*}, \dots, x_M^{j^*}$ are the amount of input m to DMU j^* ; and j^* is the DMU under consideration. The efficiency is usually constrained to be between zero and one. A unit can be made efficient either by reducing the input levels and getting the same output (input orientation) or by increasing the output level with the same input level (output orientation). The input oriented analysis is becoming more common in DEA applications because profitability depends on the efficiency of the operations.

In this study the DEA technique is used for some integrated decision making approaches. Candidate locations in each region (district) considered as DMUs. The attributes divided to two groups; negative attributes as input group and positive attributes as output in DEA method. The model of CCR-input oriented used to rank DMUs based on their efficiency scores. Then the efficient DMUs will be selected to use in TOPSIS. A summary of DEA approach has been shown in Fig. 4.

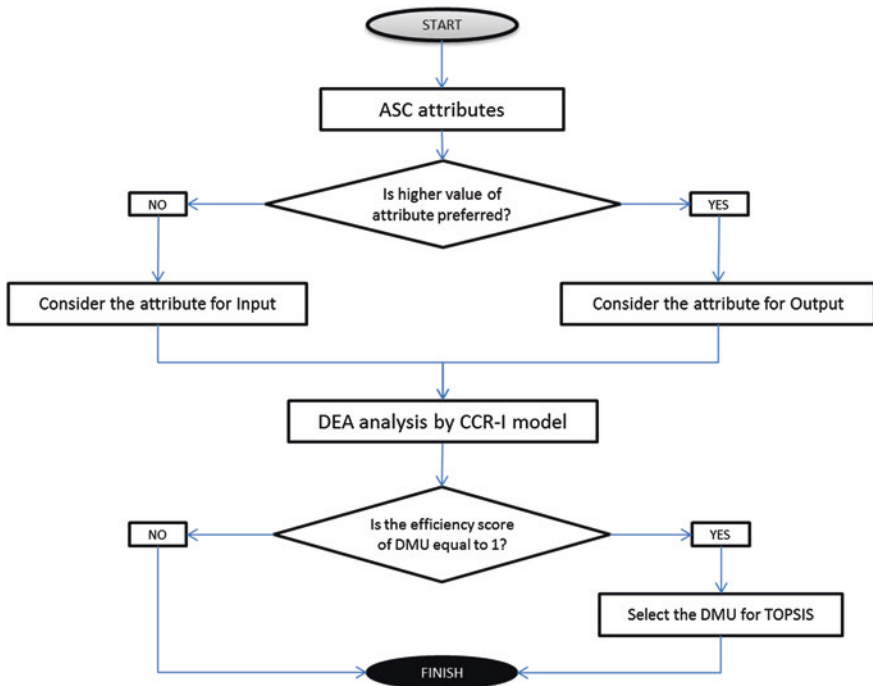


Fig. 4 DEA procedure used in this chapter

2.7 Simple Additive Weighting (SAW) Technique

Simple Additive Weighting (SAW) method is one of the most popular and most widely used methods because of its simplicity (Shakouri et al. 2014). It assumes additive aggregation of decision outcomes, which is controlled by weights expressing the importance of attributes. SAW uses all attribute values of an alternative and uses the regular arithmetical operations of multiplications and summations.

Usually the results of MADM methods are different, so their results should be compared and best rank for alternatives selected. Friedman test can be applied to compare different related samples. If the results of Friedman test showed that there is no meaningful difference between rankings, so to use the benefits of all developed MADM methods, the median of all ranking for each alternative can be used. Otherwise the best ranking method should be selected.

2.8 New MADM Technique

Since the mentioned MADM methods might be able to lead to best solution, another MADM methodology developed for them. In this technique first a hierarchical model is developed to create decision attributes for ASCLP. The summary of proposed MADM method has been shown in Fig. 5.

To find the priority of the ASC location selection attributes, a FAHP survey was designed and performed. The local weights of relative importance are computed to the attributes against the objectives; and also the global weights, which are the relative importance attributes against the goal. To derive the global weight of each attribute, its local weight was multiplied by the local weight of each corresponding objectives (Zangeneh et al. 2014).

To select best candidate location for ASCs, some sub-attribute for each location attribute were defined which can easily be measured. The Eq. 14 can be used for calculating the value of each attribute for each candidate location:

$$\chi_{ij} = \sum_{k=1}^p \tilde{C}_k \quad \forall i,j \quad (14)$$

where, k is the index of sub-attribute, and $\tilde{C}_k$ is the normalized value of sub-attribute k .

Since the unit of the sub-attributes is different, to sum and use them in formulations they are converted them to a normal range between one and zero before calculation of decision parameters using the Eq. 15:

$$\tilde{C}_k = \frac{C_k - \min C_k}{\max C_k - \min C_k} \quad \forall i,j \quad (15)$$

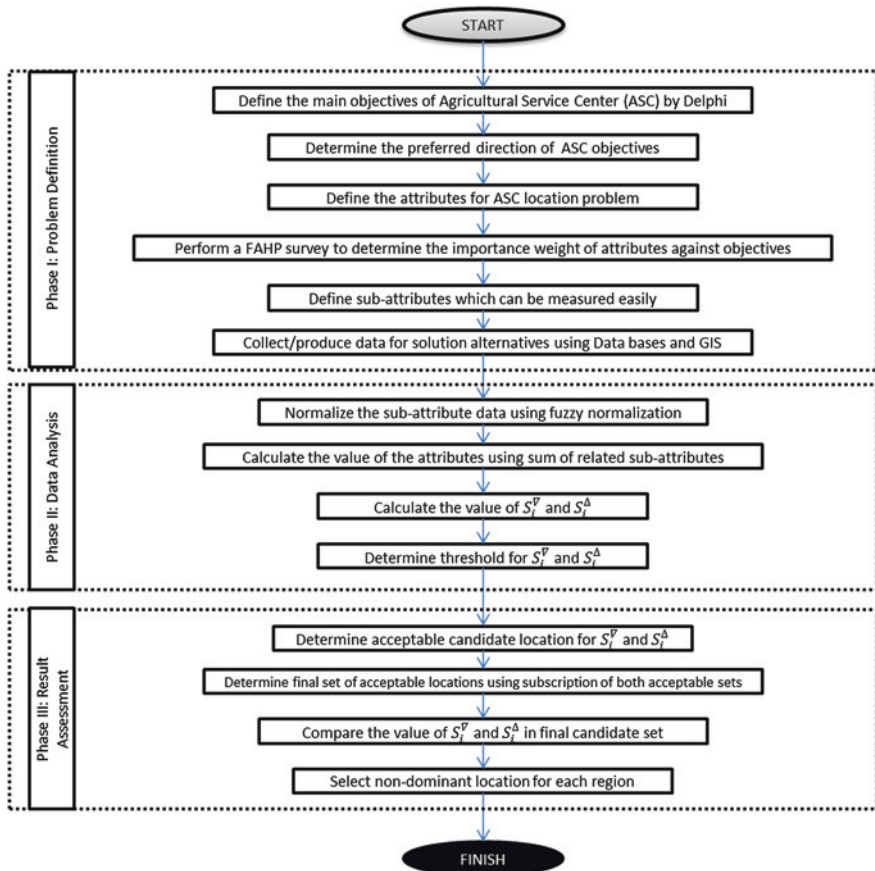


Fig. 5 The summary of developed MADM approach

There are two type of attributes viewpoint of their preferred values, i.e. there are two optimization directions: lower values of are preferred for some attributes, e.g. distances, while higher values is outrank for the ASCLP to select such candidate location for establishing ASC on it, e.g. the total cultivated area. To address two separate formulations for maxi-min and maxi-max attributes are defined (see Eqs. 16 and 17). These equations will be used to compute the suitability of candidate locations for service center establishment.

$$S_i^{\nabla} = \sum_{j=1}^n \gamma_j [\chi_{ij}] \quad (j = 1, 3, 4) \quad (16)$$

$$S_i^{\Delta} = \sum_{j=1}^n \gamma_j [\chi_{ij}] \quad (j = 2, 5) \quad (17)$$

where:

- i The index of candidate locations and demand points.
- j The index of attributes of service center location problem.
- S_i^∇ The final score of candidate location i for attributes which lower values of them are preferred (maxi-min).
- S_i^Δ The final score of candidate location i for attributes which greater values of them are preferred (maxi-max).
- γ_j The important weight of attribute j obtained from FAHP.
- χ_{ij} The value of attribute j for candidate location i .

After calculating the final scores of each candidate location, they will be ranked based on their score values. Then candidate locations which their score of maxi-min score (S_i^∇) is lower than a threshold ($\alpha\%$ of the selected range which identified by decision maker) and also for maxi-max score (S_i^Δ) which is bigger than a threshold ($\beta\%$ of the selected range which identified by decision maker) will be selected and categorized in two set of A_ρ and B_ρ for each region of study (see Eqs. 18 and 19).

$$A_\rho = \left\{ i \mid S_i^\nabla \leq \alpha\% \text{ of the selected range} \right\} \quad (18)$$

$$B_\rho = \left\{ i \mid S_i^\Delta \geq \beta\% \text{ of the selected range} \right\} \quad (19)$$

At last step of this approach, we will select locations which satisfy both selection constraints described before. Since we are going to select at least one location for each region to open a service center, locations will be selected from the set adhering to the subscription set of A_ρ and B_ρ (see Eq. 20):

$$Y_\rho = A_\rho \cap B_\rho \quad (20)$$

where:

- ρ The index of region $\rho = (1, \dots, 7)$.
- A_ρ The set of candidate locations which has been selected the using minimization selection criteria.
- B_ρ The set of candidate locations which has been selected the using maximization selection criteria.
- Y_ρ The final selected locations for region ρ .

After finding the set of Y_ρ , the best location must be proposed, because more than one location may satisfy the selection conditions. In classic location models a distance function is always used to select the best location (Franco et al. 2008). However, in this case due to the characteristics of agricultural services other attributes in addition to distance function are adopted. These further attributes enables to also consider the technical aspects of potential locations.

To prove the capability of the proposed sub-attributes and the developed multi-attribute decision making process, one case study has been conducted in a region of Iran. The studied region is Razan, a county located on the north of

Hamadan province of Iran. The Hamadan province has 1.2 % of the total area of the country and is located in the west of Iran, within $36^{\circ} 40'$ latitude and $48^{\circ} 31'$ longitude. The total area of this province is 1,494,400 ha, and the farming area is 660,000 ha, with a share of 44.16 % (Zangeneh et al. 2010). The county is subdivided into three regions: the Central region, Sardrood region, and Qorveh-e Darjazin region. Also each region divided to some districts and totally there is seven districts in the studied county.

3 Results and Discussion

At first based on the main objectives of development of ASC policy and by consulting agricultural experts using Delphi method, four objectives were made for ASCLP which are shown in Fig. 6. It is a fair comparison that the objectives constructed here are the main objectives of agricultural supply chain. To attain these objectives, candidate locations must be selected based on their attributes which are in accordance with the objectives as described in the following:

1. Maximize service quality: by minimizing the distance of service centers to the gas stations, spare parts, repair, machinery customer service center, input markets, crop markets, county center and province center.
2. Minimize service cost: by minimizing the distance of service centers to other villages, by minimizing the distance of service centers to the gas stations, spare parts, repair, machinery customer service center, input markets, crop markets, county center and province center.
3. Maximize service speed: by minimizing the distance of service centers to other villages.
4. Maximize service center profit: by maximizing cultivated area, population, number of cultivated crops, and the ration of irrigated cultivated lands to dried cultivated lands.

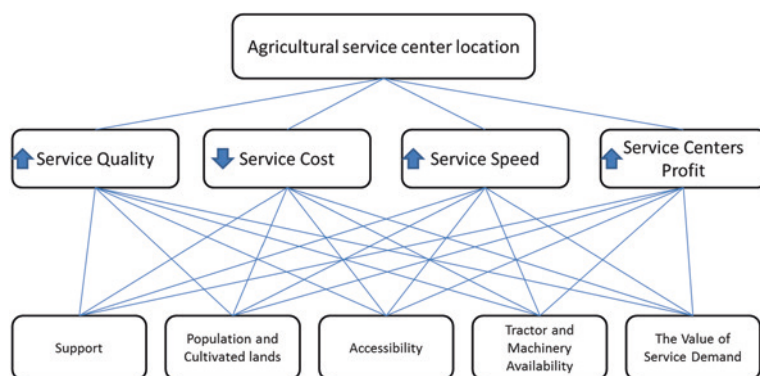


Fig. 6 Analytic hierarchy process model for location selection attributes

The sub-attribute which can be easily measured is defined (Table 2).

After defining the sub-attributes, related data has been generated/collected and then normalized. The normalized data for a district of studied region (Boqrati) is shown in Table 3.

The result of FAHP survey for importance weight of objectives and attributes of ASCLP are shown in Table 4 (Zangeneh et al. 2014).

Using the FAHP weights, the weighted score of attributes for each candidate location has been calculated (Table 5). Also Shannon's entropy is calculated for all regions and used for several MADM methods. The results of Shannon's entropy for the Boqrati district have been showed in same table.

After calculating the weighted data, six MADM methods applied which their results have been shown in Table 6 for Boqrati district. The ranking of alternatives in other districts has been identified similar to Boqrati district (see Appendix 1). The rankings of best alternatives for all districts are illustrated in Table 7.

Table 2 The attribute and sub-attribute used for ASCLP

Attribute	Sub-attribute	
Easy support χ_1	Distance to center of county (maxi-min): C_{11}	Distance to center of district (maxi-min): C_{12}
Proximity to more population and cultivated lands χ_2	The number of families (maxi-max): C_{21}	Total cultivated area (maxi-max): C_{22}
Easy access χ_3	Total distance to other villages (maxi-min): C_{31}	
Proximity to less tractor and machinery availability χ_4	Number of tractors (maxi-min): C_{41}	The value of mechanization efficiency (maxi-min): C_{42}
Proximity to more service demand χ_5	The number of crop type cultivated (maxi-max): C_{51}	The ratio of irrigated cultivated land to dried cultivated land (maxi-max): C_{52}

Table 3 The normalized sub-attribute data for Boqrati district

Candidate locations	Sub-attributes								
	C_{11}	C_{12}	C_{21}	C_{22}	C_{31}	C_{41}	C_{42}	C_{51}	C_{52}
Urte-qamish	0.000	0.022	0.270	0.252	0.031	0.298	0.595	0.500	0.102
Baba-nazar	0.255	1.000	1.000	1.000	0.446	0.000	0.000	0.667	0.053
Tape-dibi	0.262	0.733	0.273	0.235	0.465	0.536	0.158	0.500	0.145
Chahar-bolaq	0.021	0.000	0.264	0.069	0.000	0.286	0.840	0.500	0.092
Churmagh	0.341	0.314	0.591	0.443	0.370	0.393	0.000	1.000	1.000
Qeinarje	0.342	0.476	0.853	0.488	0.420	0.083	0.575	0.667	0.033
Qaderkhalaj	0.387	0.167	0.389	0.313	0.289	0.405	0.234	1.000	0.832
Qarakand	0.047	0.297	0.251	0.406	0.220	0.488	0.000	1.000	0.185
Qalejuq-zamani	0.440	0.110	0.155	0.125	0.222	0.905	0.000	0.333	0.000
Qale-zandlij	0.122	0.592	0.138	0.304	0.372	0.690	0.306	0.333	0.000
Gunduz	0.148	0.616	0.519	0.592	0.401	0.274	0.337	0.667	0.029
Mazrae-deimur	0.398	0.182	0.084	0.222	0.294	0.821	0.000	1.000	0.272
Yarmche-baq	0.158	0.551	0.202	0.157	0.323	0.714	0.581	0.333	0.000

Table 4 The local weight of location attributes which calculated by FAHP

Attribute	Importance weight ω_i
Support χ_1	0.212
Population and cultivated lands χ_2	0.202
Accessibility χ_3	0.201
Tractor and machinery availability χ_4	0.194
The value of service demand χ_5	0.189

Table 5 The FAHP and Shannon's entropy weighted attribute data for Boqrati district

Candidate locations	Attributes									
	χ_1^a	χ_1^b	χ_2^a	χ_2^b	χ_3^a	χ_3^b	χ_4^a	χ_4^b	χ_5^a	χ_5^b
Urte-qamish	0.005	0.005	0.105	0.119	0.006	0.006	0.173	0.134	0.114	0.122
Baba-nazar	0.266	0.290	0.404	0.457	0.090	0.083	0.000	0.000	0.136	0.146
Tape-dibi	0.211	0.230	0.103	0.116	0.093	0.087	0.135	0.104	0.122	0.131
Chahar-bolaq	0.004	0.005	0.067	0.076	0.000	0.000	0.218	0.169	0.112	0.120
Churmagh	0.139	0.152	0.209	0.236	0.074	0.069	0.076	0.059	0.378	0.406
Qeinarje	0.174	0.189	0.271	0.307	0.084	0.078	0.128	0.099	0.132	0.142
Qaderkhalaj	0.118	0.128	0.142	0.160	0.058	0.054	0.124	0.096	0.346	0.372
Qarakand	0.073	0.080	0.133	0.150	0.044	0.041	0.095	0.073	0.224	0.241
Qalejuq-zamani	0.117	0.127	0.057	0.064	0.045	0.041	0.176	0.136	0.063	0.068
Qale-zandlij	0.151	0.165	0.089	0.101	0.075	0.069	0.193	0.150	0.063	0.068
Gunduz	0.162	0.177	0.224	0.254	0.081	0.075	0.118	0.092	0.131	0.141
Mazrae-deimur	0.123	0.134	0.062	0.070	0.059	0.055	0.159	0.123	0.240	0.258
Yarmche-baq	0.150	0.164	0.073	0.082	0.065	0.060	0.251	0.195	0.063	0.068

^aThe results of FAHP method^bThe results of Shannon's entropy method

As can be seen in the ranking results, the ranks of candidate locations seem relatively different in all MADM methods. So the Friedman test was applied to test this hypothesis that is the results of different ranking approached are same? Table 8 has been shown the Friedman test for all MADM methods. As can be seen in the results, the Friedman tests indicate that no meaningful differences are between the MADM methods. To use the benefits of all integrated MADM methods, the median all of rankings of each candidate location has been used to determine the final ranking of each candidate location for ASC.

The high ranked locations (first to third candidates) for locating ASC on them for Boqrati district is illustrated on map in Fig. 7. The related maps of other districts can be seen in Appendix 2.

Table 6 The ranking results of six MADM approaches for Boqrati district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Urte-qamish	13	6	8	12	6	12	10
Baba-nazar	2	2	3	1	2	2	2
Tape-dibi	7	11	–	6	11	6	7
Chahar-bolaq	12	8	–	13	8	13	12
Churmagh	1	1	1	2	1	1	1
Qeinarje	3	5	6	3	5	5	5
Qaderkhalaj	4	3	–	4	3	3	3
Qarakand	10	4	2	8	4	8	6
Qalejuq-zamani	11	10	7	11	10	11	10.5
Qale-zandlij	9	12	–	10	12	9	10
Gunduz	5	7	5	5	7	7	6
Mazrae-deimur	6	9	4	7	9	4	6.5
Yarmche-baq	8	13	–	9	13	10	10

Table 7 The median of best alternative rankings for all studied districts

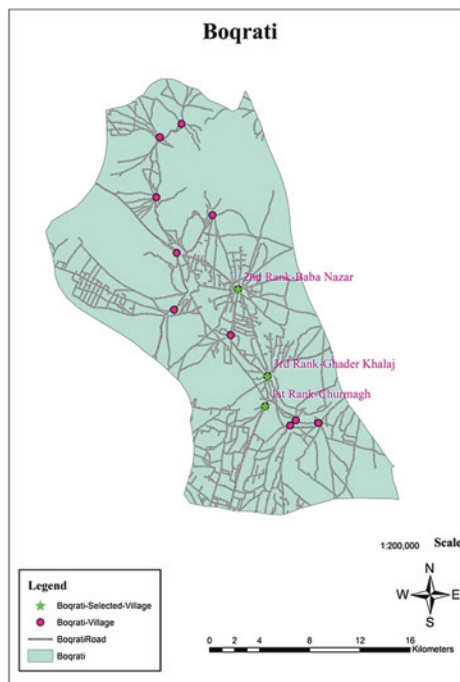
District	Best location	MADM Ranking methods						Median of rankings
		A	B	C	D	E	F	
Boqrati	Churmagh	1	1	1	2	1	1	1
Darjazin-Olia	Karafs	13	1	1	1	1	18	1
Darjazin-Sofla	Darjazin	1	6	5	1	3	1	2
Kharaqan	Dorniyan	4	1	1	5	1	2	1.5
Razan	Hariyan	20	2	1	1	1	1	1
Sardrood-Olia	Mola-bodaq	1	1	1	1	6	1	1
Sardrood-Sofla	Tulki-tape	8	1	1	1	1	2	1

Table 8 Friedman test results

District	N	Chi-square	df	Asymp. sig.
Boqrati	13	0.135	4	0.998 ^{ns}
Darjazin-Olia	22	1.448	4	0.836 ^{ns}
Darjazin-Sofla	14	0.202	4	0.995 ^{ns}
Kharaqan	15	0.191	4	0.996 ^{ns}
Razan	21	2.663	4	0.616 ^{ns}
Sardrood-Olia	11	0.262	4	0.992 ^{ns}
Sardrood-Sofla	14	1.297	4	0.862 ^{ns}

^{ns}Not significant

Fig. 7 The position of solutions on the map of Boqrati



The first rank candidate location of some districts is not acceptable; such as Kharagan, Razan and Sardrood-Sofla (see Appendix 2). So the new MADM approach used for these districts and the results are more acceptable.

3.1 Results of New MADM Approach

The values of all attributes have been calculated using their related sub-attributes for each candidate location in each region. Then by multiplying attributes and their related weights, which has been estimated using FAHP, the value of final maxi-min and maxi-max scores calculated for them. To clarify the computations, the attribute and final score of Boqrati region has been shown in Table 9.

The calculations of final scores for other regions have been done similar to the Boqrati region.

Using the defined set conditions, candidate location which satisfies the selection condition in each region has been selected and the results are illustrated in Table 10.

As can be seen in last column of Table 10, more than one candidate location satisfies the selection condition. So in this phase the aim is to select the best one for each region. In other words the non-dominated solution for this decision problem should be found. The final score of the selected candidate location in districts

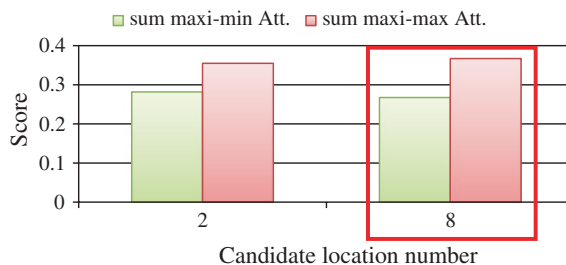
Table 9 The results of attributes in district of Boqrati

Candidate location	χ_1	χ_2	χ_3	χ_4	χ_5	S_i^∇	S_i^Δ
Chaharbolaq (1)	0.243	0.040	0.066	0.133	0.065	0.441	0.104
Urteghamish (2)	0.307	0.081	0.059	0.187	0.067	0.553	0.147
Yaremchebaq (3)	0.095	0.045	0.007	0.101	0.000	0.203	0.045
Qeinarje (4)	0.224	0.261	0.000	0.237	0.101	0.462	0.361
Gunduz (5)	0.294	0.210	0.008	0.252	0.100	0.553	0.310
Ghalezandlij (6)	0.251	0.063	0.102	0.169	0.000	0.523	0.063
Ghaderkhalaj (7)	0.193	0.120	0.041	0.247	0.346	0.481	0.466
Tapedibi (8)	0.159	0.078	0.009	0.237	0.075	0.405	0.153
Ghalejughzamani (9)	0.293	0.028	0.201	0.194	0.000	0.688	0.028
Mazraedeimur (10)	0.277	0.033	0.170	0.212	0.241	0.659	0.274
Churmagh (11)	0.289	0.193	0.138	0.304	0.378	0.730	0.571
Babanazar (12)	0.016	0.404	0.105	0.388	0.105	0.510	0.509
Gharakand (13)	0.303	0.110	0.172	0.283	0.224	0.758	0.334

Table 10 The set of selected locations in each region

Region	A_ρ	B_ρ	Y_ρ
Boqrati	1, 3, 4, 7, 8, 12	4, 5, 7, 11, 12, 13	4, 7, 12
Darjazin-Olia	2, 3, 4, 6, 7, 8, 10, 12, 13, 14, 15	3, 4, 6, 8, 9, 10, 14, 15	3, 4, 6, 8, 10, 14, 15
Darjazin-Sofla	2, 3, 4, 5, 6, 9, 10	1, 5, 6, 9, 10, 12, 14	5, 6, 10
Kharaqan	2, 3, 4, 5, 6, 8, 10	2, 7, 8, 9, 11, 12, 15	2, 8
Razan	2, 3, 4, 5, 7, 8, 9, 10, 14, 17	1, 5, 6, 7, 10, 13, 15, 17, 20, 21	5, 7, 10, 17
Sardrood-Olia	1, 2, 3, 6, 7	2, 4, 6, 9, 11	2, 6
Sardrood-Sofla	2, 3, 5, 6, 7, 8, 10	1, 2, 4, 5, 6, 13, 14	2, 5, 6

$\alpha = 50\%$, $\beta = 50\%$

**Fig. 8** The chart of selected locations of Kharaqan

which their solutions were not acceptable by first approach has been shown in Figs. 8, 9 and 10, respectively. Usually in location decisions, distance and transportation play a very important role. So the role of maxi-min attributes, which contain different distance functions are highlighted, in selecting the best solutions.

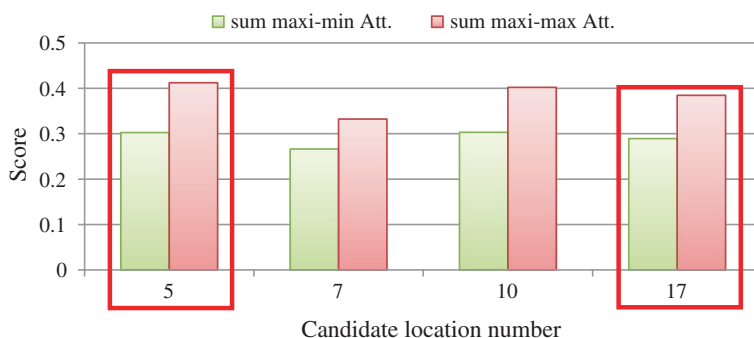


Fig. 9 The chart of selected locations of Razan

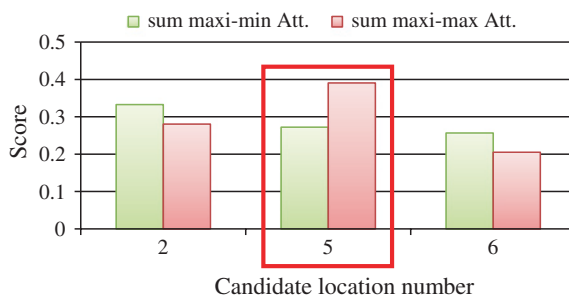


Fig. 10 The chart of selected locations of Sardrood-Sofla

As can be seen in these figures, in some regions, e.g. Boqrati, there is no unique non-dominated solution. In the Boqrati region, S_4^∇ is lower than S_7^∇ while S_7^Δ is higher than S_4^Δ . In this situation no one solution can dominate the other one. In such cases all non-dominated solutions are proposed and this is the main disadvantage of proposed approach, while it has several advantages such as simplicity of calculations, the ability to consider inherent specification of agricultural activities. The attributes considered in this research can improve the success of locating and activity of ASCs. The non-dominated solutions for Kharaqan, Razan and Sardrood-Sofla have been illustrated by red rectangular in Figs. 8, 9 and 10. The results of other districts can be seen in Appendix 3.

The position of selected solutions of Boqrati, Kharaqan, Razan and Sardrood-Sofla have been shown in Figs. 11 and 12 to clarify the power of proposed multi attribute decision making approach.

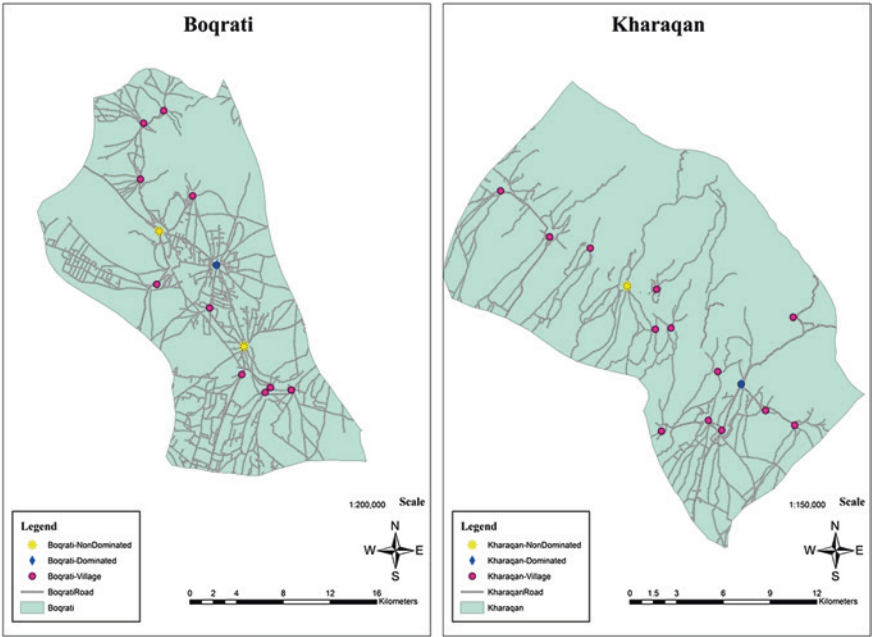


Fig. 11 The position of solutions on the map of regions Boqrati and Kharaqan districts

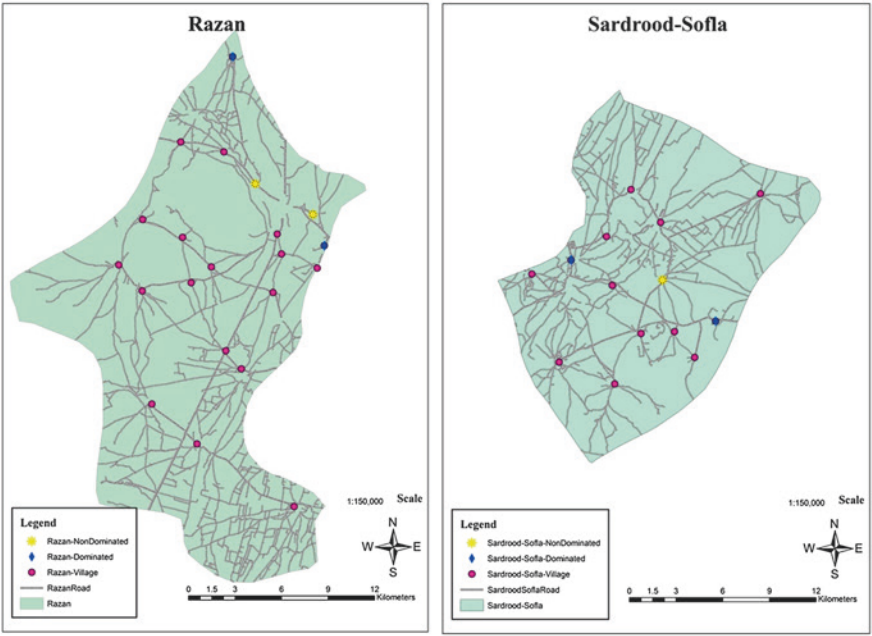


Fig. 12 The position of solutions on the map of regions Razan and Sardrood-Sofla districts

In Darjazin-Olia, the non-dominated locations are not in the center of the region, similar to the Boqrati region. This has happened because of attributes which are added to this location problem; i.e. distance to district and county centers. Since the service center needs to be supported by some suppliers for some inputs, they are should be near to these centers. For example the market of agricultural inputs, fuel stations, spare parts, and also the market of agricultural products are always placed in county and district centers.

Like what was described for Darjazin-Oila, similar results can be seen in the Razan district. In this region, the proximity to center of the county plays the main role in the location of the service center.

4 Conclusion

In this chapter which constitutes part of large project, several fast and intelligible approaches to solve an important agricultural facility location problem are developed. All aspects of agricultural service location problem have been considered, i.e. from the viewpoint of customers, service suppliers, and also technical suitability of candidate location for locating the service center on them. Some multi criteria decision making methods used to find optimum location for ASC. These methods enable strategic managers to taking to account sustainability items for location selection decisions in the subject of agricultural services. In classic location models just distance and demand weight be mentioned, but in developed approach moreover other items included. The proposed approach can be used in other regions and also other service location problems with some modifications. If the results of ranking methods be different or not median of ranking results which introduced in this chapter can lead to a near to optimum solution, because each method has its different way to find rankings. The main limitation of proposed approach is the non-dominated solutions which occurred in some case studies. In this case further research is required to overcome this.

Acknowledgments The financial support provided by University of Tehran is duly acknowledged. Thanks and appreciations of authors also go to colleagues in developing the research and people who have willingly helped us with their abilities.

Appendix 1: The Ranking Result of MADM Approaches

See Tables [11](#), [12](#), [13](#), [14](#), [15](#) and [16](#).

Table 11 The ranking results of six MADM approaches for Darjazin-Olia district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Pelikan	15	12	–	11	11	7	11
Pirbag	7	3	–	22	8	22	8
Tamuzan	8	13	–	14	18	8	13
Javarsajin	4	9	5	9	12	2	7
Rakin	9	16	–	8	19	5	9
Sonqorabad	16	2	2	6	4	9	5
Sangeran-kuh	21	18	6	17	20	17	17.5
Suzan	3	11	–	2	2	1	2
Shanjur	12	21	–	10	17	14	14
Shavand	6	4	–	4	3	12	4
Ein-abad	10	17	–	3	5	3	5
Qaraqie	19	22	–	16	22	19	19
Kaj	1	5	4	7	6	6	5.5
Karafs	13	1	1	1	1	18	1
Gol-tape	20	15	3	15	15	11	15
Mazrae-sarem	18	6	–	12	10	10	10
Manuchehr	14	7	–	18	9	20	14
Mising	11	10	–	20	13	16	13
Nakin	17	20	–	13	21	13	17
Valashajard	5	14	–	19	14	15	14
Vasmaq	2	8	–	5	7	4	5
Yengeje-karafs	22	19	–	21	16	21	21

Table 12 The ranking results of six MADM approaches for Darjazin-Sofla district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Ahmad-abad	12	13	–	11	14	8	12
Behkandan	7	3	1	7	5	7	6
Poshtejin	4	7	–	6	8	2	6
Hakan	11	1	3	5	1	13	4
Darjazin	1	6	5	1	3	1	2
Razin	13	11	–	12	11	12	12
Zakan	14	5	6	14	9	14	11.5
Sayan	8	2	2	8	4	10	6
Salilak	10	10	–	13	10	11	10
Aman	3	12	–	4	7	5	5
Kamandan	9	14	–	9	13	6	9
Nezam-abad	2	9	–	3	6	4	4
Nudeh	6	8	–	10	12	3	8
Neer	5	4	4	2	2	9	4

Table 13 The ranking results of six MADM approaches for Kharagan district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Amir-abad	2	4	–	6	5	8	5
Aqche-kharabe	10	8	–	11	7	9	9
Aqchai	12	15	–	9	13	10	12
Badkuh	11	9	–	14	10	14	11
Jaryanloo	13	3	3	8	2	4	3.5
Khalaj	9	13	–	12	15	12	12
Dorniyan	4	1	1	5	1	2	1.5
Sarijloo	14	5	2	3	4	1	3.5
Surtejin	3	11	–	4	12	7	7
Karvaneh	6	12	–	7	11	6	7
Garmak	15	7	–	15	8	13	13
Gavanloo	5	2	–	13	3	15	5
Lale-dan	8	6	–	1	6	3	6
Mahnian	1	10	–	2	9	5	5
Vahandeh	7	14	–	10	14	11	11

Table 14 The ranking results of six MADM approaches for Razan district

Candidate location	MADM ranking methods						Median of rankings
	A	B	C	D	E	F	
Amiriyeh	9	13	–	10	14	5	10
Abbarik	13	5	–	5	4	9	5
Aqkand	17	14	–	19	15	18	17
Tazeh-kand	15	20	–	16	19	14	16
Tekye	8	16	–	12	17	8	12
Jamishloo	18	7	–	7	6	11	7
Khomigan	5	11	–	11	9	12	11
Sirab	7	8	–	15	10	13	10
Qazyatan	19	9	–	21	12	20	19
Qolamali	12	17	–	14	16	10	14
Farsejin	2	10	–	3	7	4	4
Qater-olan	21	15	–	20	20	19	20
Kahard	6	1	–	4	2	15	4
Mad-abad	10	19	–	18	18	16	18
Navar	1	4	2	2	3	2	2
Nianj	16	18	–	9	13	7	13
Hariyan	20	2	1	1	1	1	1
Varqestan	4	3	–	13	5	21	5
Varvazin	14	21	–	17	21	17	17
Vafs	11	6	3	8	8	6	7
Yenge-qaleh	3	12	–	6	11	3	6

Table 15 The ranking results of six MADM approaches for Sardrood-Olia district

Candidate location	MADM Ranking methods						Median of rankings
	A	B	C	D	E	F	
Ojaq	7	9	–	9	1	10	9
Arpa-dareh	8	6	–	8	2	9	8
Aqche-kharabeh	11	11	3	6	8	8	8
Takht	4	4	–	4	5	4	4
Chopoqloo	9	10	–	7	11	5	9
Khorvandeh	2	2	–	5	4	6	4
Qarebolaq	5	8	–	2	10	2	5
Kahriz-boqazi	3	3	–	11	9	11	9
Gavsavar	6	5	–	3	3	3	3
Mola-bodaq	1	1	1	1	6	1	1
Mansoor-abad	10	7	2	10	7	7	7

Table 16 The ranking results of six MADM approaches for Sardrood-Sofla district

Candidate location	MADM Ranking methods						Median of rankings
	A	B	C	D	E	F	
Payandeh	6	12	–	9	11	10	10
Pilejin	10	7	–	11	8	11	10
Tulki-tape	8	1	1	1	1	2	1
Jafar-abad	12	11	5	8	9	9	9
Chal-boqa	7	9	–	7	7	8	7
Chayan	4	4	6	4	4	4	4
Khanjar-abad	1	5	–	5	5	5	5
Serleh	13	8	–	10	10	6	10
Soltan-abad	2	2	2	3	2	3	2
Qayesh	3	3	3	2	3	1	3
Qeraylar	14	10	–	14	12	13	13
Qozlijeh	9	14	–	12	14	12	12
Qale-shater-bali	5	6	–	6	6	7	6
Viar	11	13	–	13	13	14	13

Appendix 2: The Position of High Ranked Solutions for All Regions by Six MADM Methods

See Figs. 13, 14, 15 and 16.

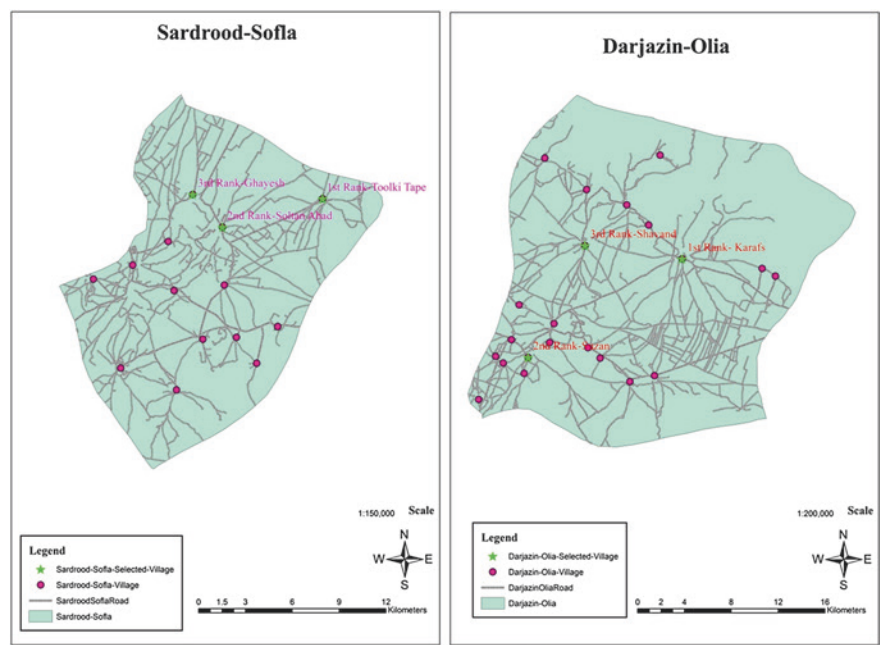


Fig. 13 The position of solutions on the map of Sardrood-Sofla and Darjazin-Olia districts

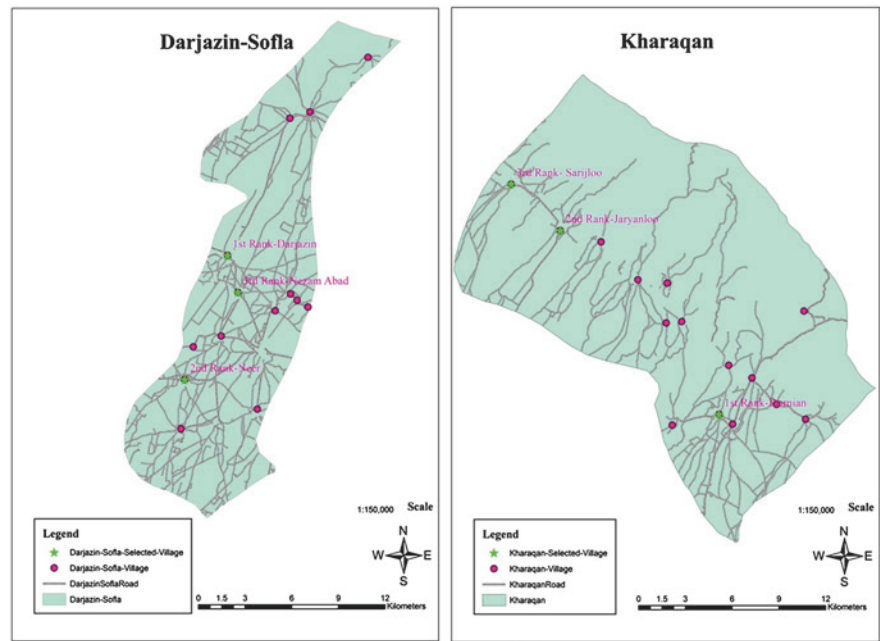


Fig. 14 The position of solutions on the map of Darjazin-Sofla and Kharaqan districts

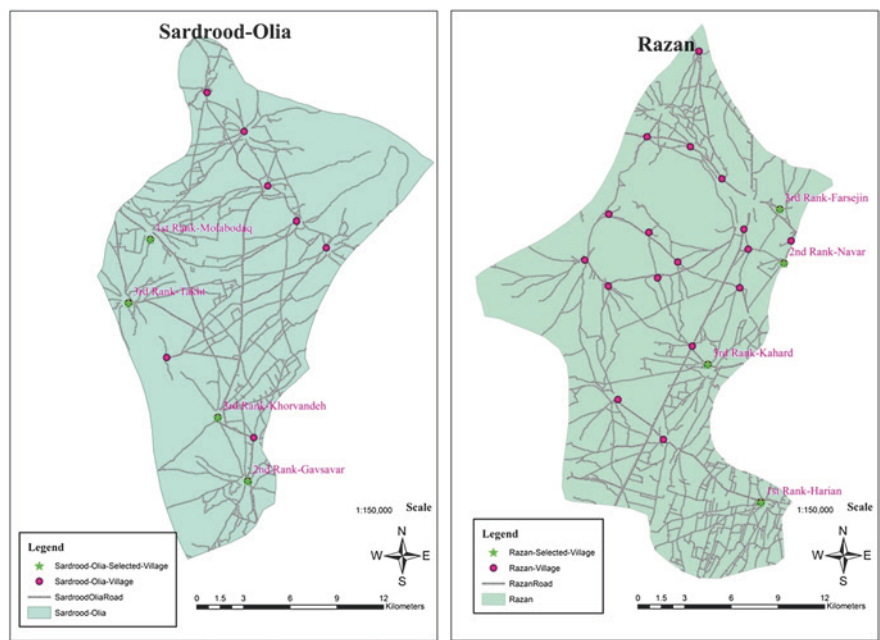
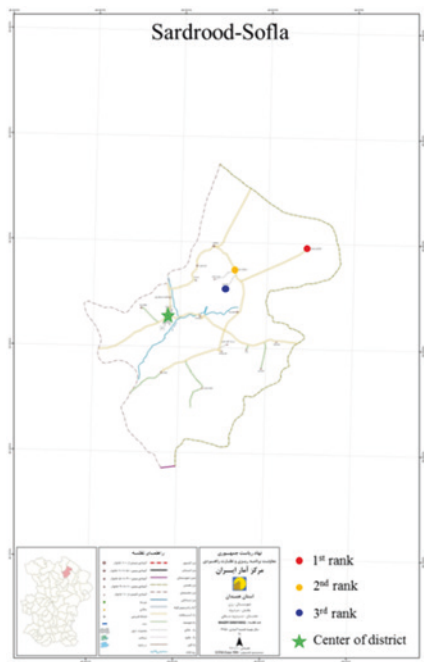


Fig. 15 The position of solutions on the map of Razan and Sardrood-Olia districts

Fig. 16 The position of solutions on the map of Sardrood-Sofla district



Appendix 3: The Final Location Selection Charts
by New MADM Method

See Figs. 17, 18, 19 and 20.

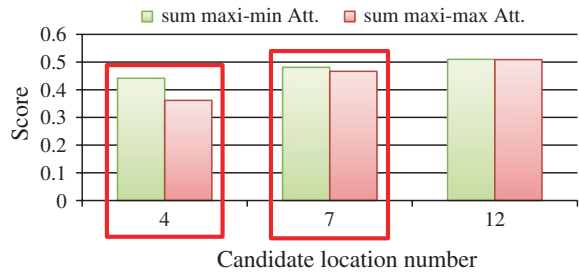


Fig. 17 The chart of selected locations of Boqrati

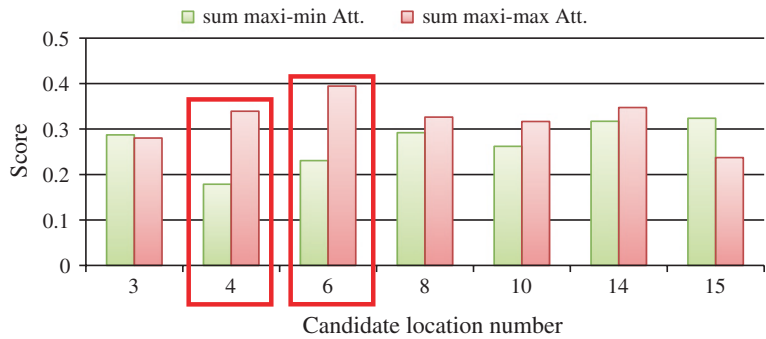


Fig. 18 The chart of selected locations of Darjazin-Olia

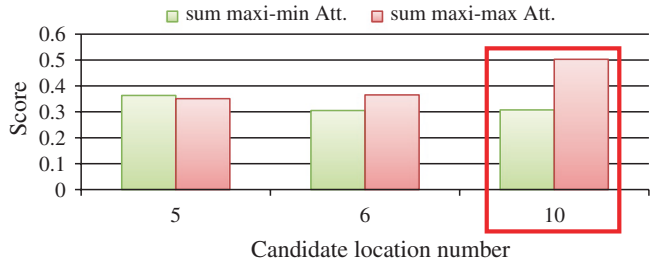


Fig. 19 The chart of selected locations of Darjazin-Sofla

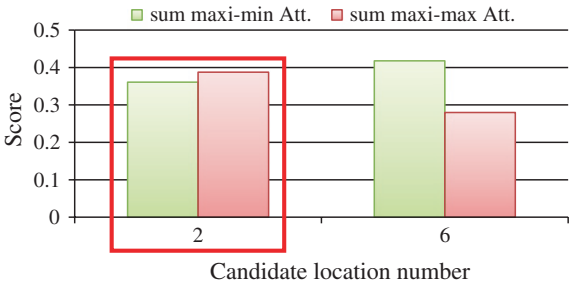


Fig. 20 The chart of selected locations of Sardrood-Olia

Appendix 4: The Position of Solutions on the Map of Three Districts by New MADM Approach

See Figs. 21 and 22.

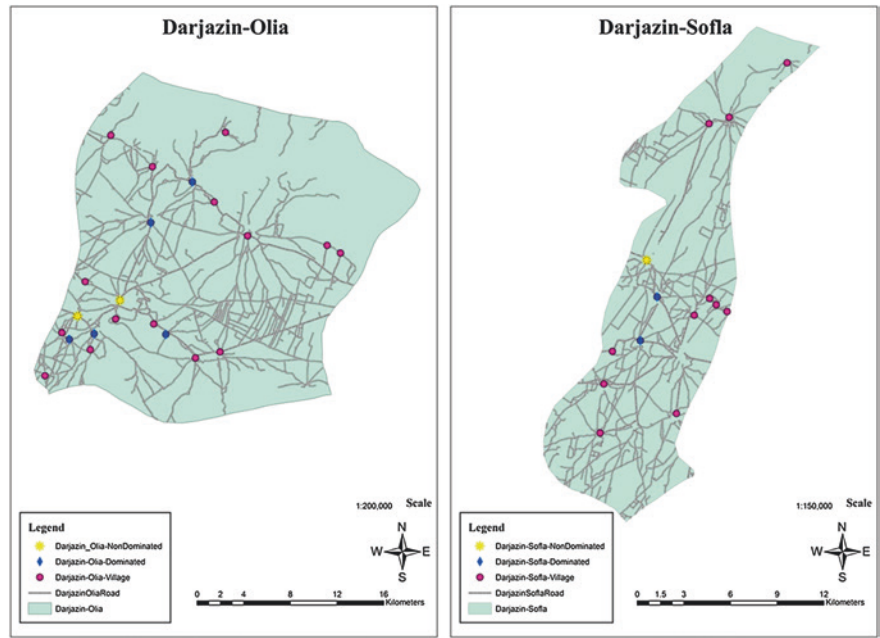
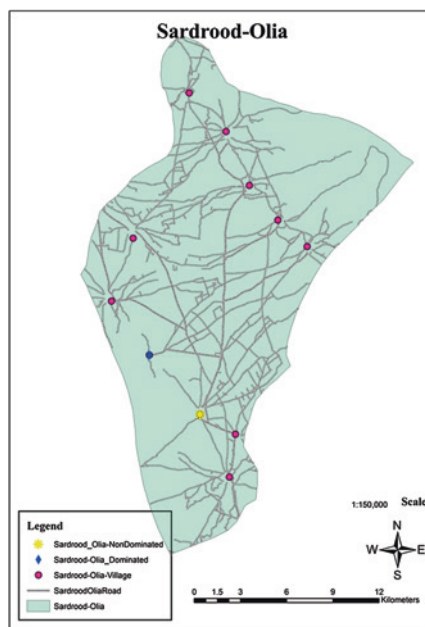


Fig. 21 The position of solutions on the map of regions Darjazin-Olia and Darjazin-Olia districts

Fig. 22 The position of solutions on the map of regions Sardrood-Olia district



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