Developing location indicators for Agricultural Service Center: a Delphi–TOPSIS–FAHP approach

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(Received 24 November 2014; accepted 25 January 2015)

The main goal of this paper is to construct objectives and attributes of the service centers location problem. This problem is often found within production management as a location problem, when designing for example supply chains or manufacturing layouts. The main contribution of this paper is constructing related location indicators. Since there was no similar literature in this discipline, so a Delphi survey applied to quantify expert’s attitudes about location problem of Agricultural Service Center (ASC) and construct location selection attributes and also ASC objectives. A TOPSIS survey is done to rank extracted attributes to import in fuzzy analytical hierarchy process (AHP) study. Then a fuzzy AHP technique is applied to compute the weight of these most important attributes using four objectives, which obtained by Delphi technique too. In the simplest form with this assumption that all objectives have the same priority, the results illustrated that the service, cost, speed, and ASC profit are first to last important objectives, respectively. At the end of this paper, the multi-choice goal programming method recommended to use when the priorities of objectives are not the same. Finally, the weight of ASC location attributes computed to consider in ASC location problem.

Keywords: Agricultural Service Centers (ASC); location; objectives; attributes; service

1. Introduction

Each member of supply chain needs to perform specific functions or activities in value addition process. Performance of supply chain could be improved if supply chain is integrated and the concerned activities are properly coordinated (Shukla, Garg, & Agarwal, 2014). Energy, labor, input costs, markets conditions, crop yielding and prices, machinery service availability, pest and disease infection, environmental conditions, and even economic and political strategies change the agricultural productivity in the supply chain (Lak & Almasi, 2011). Among these dynamic variables, providing agricultural services in the right way can have a strategic role to improve the agricultural productivity. Several services can be given to the whole of agricultural supply chain. These problems can be seen as analog to facility location problems in supply chains or design problems inside physical manufacturing systems. Some services are for farms, specifically. In following section, four types, including input supply, mechanization services,
advisory services, and financial services, which are considered in this research, are introduced.

A wide range of location problems effect today’s firm and organizational objectives and decision-makings. The interest and service level, economic profits, quality of service, security, environmental protection, availability, and optimum performance are some of the many criteria and objectives of the facility location problem; and hence, different methods and approaches have been employed in the literature to maximize the achievement of these objectives (Hosseini-Nasab, Tavana, & Yousefi, 2014).

1.1. Input supply service

Unfortunately after market liberalization, a majority of the farm input supply companies remains concentrated in urban areas or central rural zones. Due to these changes millions of poor farmers in rural areas do not have access to agricultural inputs on time and in right way, such as improved seeds, chemical fertilizers which are needed to help them improve their productivity. So poor development and weak performance of rural agricultural input markets explain the current low productivity of small holder farmers (Dorward & Chirwa, 2011).

1.2. Agricultural mechanization service

The manufacture, distribution, repair, maintenance, management and utilization of agricultural tools, implements, and machines are covered under mechanization services (Lak & Almasi, 2011). The important point in mechanization services is that how supply mechanization services to the farmer in an efficient and effective manner. If mechanization is implemented in the right way, it will have a considerable effect on agricultural productivity improvement (Lak & Almasi, 2011). In many countries, agricultural mechanization has made a significant contribution to the agricultural and rural development. After applying farm mechanization levels of production have increased, soil and water conservation measures were constructed, the profitability of farming improved, the quality of rural life enhanced, and development in the industrial and service sectors was stimulated so mechanization services are highly required to be supplied in an effective way (Bishop, 1997). Inns (1995) mentioned that agricultural mechanization development depends on the farmers’ satisfaction and capability to identify opportunities for achieving sustainable benefits by improved and/or increased use of power and machinery, selecting the most worthwhile opportunity and carrying it through to successful implementation. Lack of consideration to the necessity of development in mechanization of agricultural sector, insufficient cooperation between industrial and agricultural sector, and unrealistic selection of goals and objectives and perhaps, more importantly misuse and poor management of resources could all be counted toward the considerable fall back in the agricultural sector (Bagheri & Moazzen, 2009). Sims and Kienzle (2009) have done three mechanization supply chain case studies in three countries. They presented five elements for mechanization supply chain (see Figure 1).

The role and activity of machinery hire service stakeholders should include following aspects: Coordination with other stakeholders; Business management; Quality control; Operator training; Maintenance and servicing; and closely follow farmers’ needs (Sims & Kienzle, 2009). The previous papers did not consider to efficient manner of supplying and distributing the mechanization services for customers. In current research the strategy of providing mechanization services with all other agricultural services is
considered. Therefore, supplying high quality mechanization services in coordination with the needs of farms by Agricultural Service Centers (ASCs) can lead to the improvement of productivity in whole supply chain of agricultural production.

1.3. Agricultural advisory service

Agricultural consulting services are known as activities that make new knowledge available to the agricultural producers and assist them to improve their farming and management skills. The services may include: Sharing the information, training and advice of farmers, testing new technologies on farms, and developing farm management tools. The basic indicators for success of a demand-driven advisory service system in agriculture are: (a) farmers have access to agricultural advisory services; (b) farmers use the advisory services; (c) advices lead to income’s increase from the agricultural production; and also (d) competition among agricultural advisers (Chipeta, 2006). Altogether, the advisory is a critical need to the agricultural supply chain and the access to this service must be easy to encourage the farmers to use it. This can be obtained by locating service centers in accurate places. The demands from farmers in many cases are different. The advisory service demands which are formulated by various stakeholders of agricultural supply chain can be seen in Figure 2.

1.4. Financial service

Access to external financial resources in agriculture is constrained. This is due to low enterprise profitability in agriculture, accumulated debts, high inflation, risk and uncertainty, and collateral problems (Johan, Swinnen, & Gow, 1999). 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, etc. So increasing the access to financial services including loan and insurance can improve the productivity in agriculture.
Agriculture is the only major sector that uses the land surface as an essential input into its production function. This wide geographical dispersion of agricultural production has the important economic consequence; transportation becomes essential. Output must be transported for consumption by others and inputs; such as modern seeds, fertilizer, pesticides, or machinery, and all required agricultural services must be transported to the farm to raise output (Timmer, Falcon, & Pearson, 1983). Therefore, to success in providing and distributing agricultural services for improvement of productivity in this sector, the right location of such service centers should be selected. In this regard, one of the initial steps to solve this location problem is finding related location objectives and attributes to use in multi-criteria decision-making (MCDM) location models. In following section the multi-attribute decision-making (MADM) and multi objective decision-making (MODM) techniques is reviewed and appropriate decision-making technique for ASC location problem is selected.

In a complementary study from the authors of this paper, a MADM approached developed, to use the attributes and objectives extracted in this study, and best candidate locations for establishing service centers for agricultural production identified (Zangeneh, Nielsen, Akram, & Keyhani, 2014).

1.6. **MADM and MODM decision-making techniques**

There are various techniques for ranking alternatives. In many real-world problems, the decision-maker likes to pursue more than one target or consider more than one factor or measure, which called MODM problem and MADM problem. There are many decision-making problems that their information is spatial and known as location
decisions problems. Facility location is a branch of operation’s research related to locating or positioning at least a new facility among several existing in order to optimize at least one objective function (Farahani, Steadisefi, & Asgari, 2010).

There are many techniques which are used to solve the MADM problems. The most popular ones are as follows: lexicographic, permutation method, simple additive weighting (SAW), elimination and choice expressing reality (ELECTRE), technique for order preference by similarity to ideal solution (TOPSIS), linear programming techniques for multidimensional analysis of preference (LINMAP), and interactive SAW method and MDS with the ideal point (Hwang & Yoon, 1981a).

Also there are many techniques which are used for the MODM problems. The most popular ones are as follows: metric LP methods, bounded objective method, lexicographic method, goal programming (GP), goal attainment method, method of Zionts–Wallenius, the methods as step method (STEM) and related method, sequential multi-objective problem solving and sequential information generator for multi-objective problems method, GP STEM, and C-constraint method and adaptive search method (Hwang & Masud, 1979; Szidarovszky, Gershon, & Duchstein, 1986; Ulungu & Teghem, 1994; Zionts, 1979). Also, papers such as the work by Do et al. could be considered relevant as they combine simulation under uncertainty with heuristics to find suitable solutions.

The analytic hierarchy process (AHP) is widely used by authors to solve MADM problems. García et al. (2014) generated a multi-criteria and multi-attribute assessment model that allows selecting the ideal location for warehouses for perishable agricultural products. In another paper, Akınci, Özlup, and Turgut (2013) determined suitable lands for agricultural use in Turkey by AHP. As García et al. (2014) newly reviewed the literatures, no papers has been seen, which focused on ASC location problem. A good paper on implementation of Fuzzy AHP and Delphi method in MADM problems is Cho and Lee (2013). They identified four decision areas and further prioritized the sixteen factors under a hierarchy model structured by Fuzzy AHP approach.

Location and the number of ASCs in each region is a key parameter to ensure the success of agricultural servicing. So the main scope of this study is constructing indicators for location selection of ASCs to improve the performance of agricultural supply chain viewpoint of productivity, quality, and competitiveness. Secondly, to give primary weight to the objectives and location attributes, Fuzzy AHP method is used. Also specifying the final weight of location attributes using GP method is provided at last step of this study. In other words an integrated approach which combines MADM and MODM is developed. First to third phase belongs to MADM and fourth phase is a MODM problem. Also GP is used to generalize proposed approach and make it utilizable for different/future real world applications. The managers can use developed approach to import their ideal values of agricultural supply chain goals to the model and get appropriate weight for the ASC location attributes. The results of current research are used in facility location problem of ASCs in another paper of the authors.

2. Material and methods

In this research, the FAHP has been used to assess the location indicators (both objectives and attributes) of ASCs. Using the FAHP method, the ASC location attributes is prioritized based on objectives, which assumed that they have same importance. But another phase added to the framework to consider the possible difference between objectives using multi-choice goal programming (MCGP), i.e. in the case that the
priorities of objectives are not the same. So this research has four main phases for assessing the location attributes (see Figure 3):

1. Constructing initial location attributes and refining them and also location objectives using Delphi method.
2. Ranking initial ASC location attributes using TOPSIS technique.
3. Developing the AHP hierarchal model containing the assessment of objectives and attributes, and determining the weights of objectives and attributes through FAHP.
4. Prioritizing the attributes through GP.

2.1. Phase I
First of all, the location problem of ASCs is defined. Often the ASC location problem occur in developing countries, but may occurs in development ones where the strategic decision be taken to improve the productivity of their agricultural supply chain. However, the problem is also well known within production, where placing central maintenance or service facilities is often a critical issue when determining the cost of supporting an ongoing manufacturing environment. Services, however, play a particularly critical role in the agricultural sector. Tractor and farm machineries are needed, but in developing countries considerable number of them are old and their efficiency has been reduced, so need to be replaced. Also other services such as advisory, input supply

![Figure 3. The schematic process of overall research framework.](image)
and financial services can improve the efficiency of agricultural production. In some developing countries (for example Iran) governments have been concluded that establishing ASCs and keep them update in the aspects of tractors, machineries, and also other agricultural services will improve the efficiency. So, the main issue for this policy is selecting the location of these centers. This problem has many aspects, but it is MADM problem and an AHP can solve it, primarily. It is common that in similar location problems, desired attributes be collected from literatures and similar studies. But in current problem no similar research study for the attributes found, so Delphi method was used to construct ASC location attributes.

2.1.1. Delphi method

Delphi is a technique of popular survey method which extract consensus of ideas among a set of experts or panelists by maintaining the unanimity among them. Delphi technique has been used for various purposes like setting goals, finding problems, developing system models, decision-making, etc. (Prusty, Mohapatra, & Mukherjee, 2010). In current research several rounds of Delphi survey is needed to construct the objectives and attributes of ASC location problem. In the following sections the process of Delphi survey has been described.

2.1.2. Delphi survey process

2.1.2.1. Design and administration of the initial questionnaire. There is no similar research about location of ASC in literatures, so the initial questionnaire was basically a brainstorming session among the selected Delphi panelists. Designer team was included four people who designed the open questions of first questionnaire and contributed in different steps of this research. The aim of this step of Delphi study was construction of the location selection indicators (both objectives and attributes) of ASC location problem. Each Delphi panelist was asked to answer two main questions as follows:

(1) What location can be appropriate to establish ASC? In other words what attributes should be considered to select a place for an ASC?
(2) What advantages can be achieved if an ASC located in best possible location (based on attributes you mentioned in previous question)? In other words what are the objectives of ASC location selection?

First question was designed to collect and construct ASC location attributes and the second to determine main objectives of ASC facility location problem. Eight experts replied to the first round questionnaire. The composition of the panelists in this round is given in Table 1.

The second questionnaire was designed with the objective of prioritizing the attributes raised in the first questionnaire and sent to the Delphi panelists. Attributes were rated with respect to priority criterion. The rating scale (see Table 2) was in the range of 1–9, with ‘1’ representing ‘not important’ and ‘9’ representing ‘very highly important’ meant that how much an attribute is important for each Delphi panelists participated in the survey to select best location of ASCs.

There are several methods to calculate the score of each attributes to determine the most important attributes to use in Fuzzy AHP method. The number of items for pairwise comparisons should be reduced in AHP to simplify judgment process and
ensure the accuracy of results. So here coefficient of variation and Delphi score are used simultaneously in a TOPSIS ranking survey to reduce the number of items.

If the absolute dispersion is defined as the standard deviation, and the average is mean, the relative dispersion is called the coefficient of variation (CV) or coefficient of dispersion. The CV is attractive as a statistical tool because it apparently permits the comparison of varieties free from scale effects, i.e. it is dimensionless. The CV is defined as the ratio of the standard deviation $\sigma$ to the mean $\mu$ (Brown, 1998) (Equation (1)):

$$CV = \frac{\sigma}{\mu}$$

(1)

The lower value of CV has preference to select one attribute as ASCs location indicator, i.e. Delphi panelist opinions is similar to each other and average of them is high about an attribute, illustrate that all panelists want to consider that attribute in study.

Another method to analysis the Delphi panelist’s scores to select best indicators is Delphi score, which proposed by Linstone and Turoff (2002) (Equation (2)):

$$\text{Delphi Score} = \frac{(\text{Lowest Score} + \text{Highest Score}) + (4 \times \text{Average Score})}{6}$$

(2)

Against the CV higher values of Delphi score is preferred. Each attribute which have the most Delphi score can be selected to include in ASCs location selection process.

### 2.2. Phase II

In this phase, the most important attributes will be selected according to their Delphi score and CV. Then the hierarchy model will be formulated, and the AHP survey can be run. Here, the TOPSIS technique is applied to rank attributes according to the value of CV and DS.

| Participant type     | Educations                                                                 | Office                                      | Number |
|----------------------|-----------------------------------------------------------------------------|---------------------------------------------|--------|
| Professor            | Ph.D. with average background of 12 years in the field of Agricultural Engineering | University of Tehran, University of Zanjan | 3      |
| Ph.D. student        | M.Sc. in the field of Agricultural Engineering                              | University of Tehran                       | 3      |
| Government expert    | B.Sc. and M.Sc. with average background of 14 years in the field of Agricultural Mechanization Engineering | Agricultural Department of Zanjan and Alborz provinces | 2      |

| Linguistic variable     | Value |
|-------------------------|-------|
| Not important           | 1     |
| Very low                | 2     |
| Medium low              | 3     |
| Low                     | 4     |
| Fair                    | 5     |
| Medium                  | 6     |
| High                    | 7     |
| Medium high             | 8     |
| Very high               | 9     |
TOPSIS is a MCDM method which is initially developed by Hwang and Yoon (Hwang & Yoon, 1981b). The technique is based on the idea that the 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 value is mentioned for positive attributes where higher values of them are preferred for the location of ASC, e.g. population of candidate location, while for negative attributes is vice versa.

2.3. Phase III
The main aim of current research is estimating the weights of objectives and attributes from the FAHP model which is developed. So the AHP questionnaire distributed to the agricultural professors and experts to respond to judge about relative weight of each pairwise comparison between objectives and attributes. In the production environment this can easily be changed to managers and production technology experts.

2.3.1. FAHP
AHP is a structured technique for organizing and analyzing complex decisions based on paired comparisons of both projects and criteria (Saaty, 1986). The strength of the AHP method lies in its ability to construct complex, multi-person, multi-attribute, and multi-period problem hierarchically (Chin, Xu, Yang, & Lam, 2008). The judgments of conventional AHP method usually have ambiguity problem because the verbal attitudes of decision-makers evaluation process contain vague and multiplicity of meaning (Lee, 2010). Thus, in order to overcome the verbal ambiguity of linguistic variables, fuzzy set theory has applied to the judgment as an extension of AHP method. Fuzzy set theory was first introduced by Zadeh (1976) to deal with the uncertainty.

2.4. Phase IV
In this research, it is assumed that the importance of all objectives is the same, but for applying this approach to any agricultural region, the managers must consider their agricultural conditions and also their strategic decision to use ASC in their region. If the managers prefer to stress some objectives, in other words the managers follows specific level of each objective function to improve the performance of their ASC, so they strictly recommended prioritizing the objectives and then use GP technique (Chang, 2007) to compute the final weight of ASC location attributes. Then they can use these weights to define the process of MADM to find best location of ASCs. Traditional GP can be used in this case when there is only one goal level in each objective function, but MCGP is another version of GP which considers several maximum or minimum goals in (Chang, Chen, & Zhuang, 2014).

3. Results and discussion
3.1. The results of Delphi survey
The answers made by the Delphi panelists to the initial questionnaire covered a wide range of issues. According to the results, the panelists mentioned number of machinery
available in the region, distances, future work condition of service centers in future, etc. Similarly, Garcia et al. (2014) constructed attributes for perishable product warehouse which relatively is an ASC including: accessibility, security, needs of the agricultural product warehouse, social acceptance that the warehouse may have on the environment where it is supposed to be built, the costs of product transportation, wages, and salaries of workers and managers. After constructing the attributes various scores were obtained in the second questionnaire against each ASC location attributes. The title and scores of both evaluation methods (i.e. CV and DS) methods have been shown in Table 3.

Based on the main objectives of development of ASC establishment policy, four objectives was made for ASC location problem shown in Table 4, by consulting agricultural experts using Delphi method (the second question in first round questionnaire is related to the objectives). It can be said that the objectives constructed here is almost the main objectives of agricultural supply chain. The quality is the first and the most important objective in any supply chain management. All actions are done to improve the quality. So this study strictly focused on quality of services in accomplishing our research. The quality of services in agricultural operations such as mechanization and inputs can directly affect the quality and quantity of production. Competitiveness of agricultural production directly related to their quality and price. The farmers always try to reduce their costs and compete with other markets. Here the location attribute is

Table 3. Score of ASC location attributes.

| No. | Attribute                                                                 | CV   | DS   |
|-----|---------------------------------------------------------------------------|------|------|
| C1  | Surplus of tractor and machinery which concentrated in region             | 0.763| 4.20 |
| C2  | Lack of tractor and machinery                                           | 0.393| 6.50 |
| C3  | Easy reach of farmers to the ASC                                         | 0.447| 5.73 |
| C4  | Easy reach to spare parts, repair, customer service center, and gas station | 0.225| 6.90 |
| C5  | Easy reach to main roads and byroads                                     | 0.553| 5.27 |
| C6  | Possibility to develop the workspace in future                           | 0.525| 5.27 |
| C7  | Minimum distance to the covered regions                                  | 0.435| 5.80 |
| C8  | Easy reach to its villages and covered regions                           | 0.313| 6.23 |
| C9  | Easy reach to water, electricity, gas, and telephone with minimum cost   | 0.484| 5.67 |
| C10 | Existence of crop rotation with least fallow (irrigated be more than dry farming) | 0.384| 5.93 |
| C11 | Social acceptance by the farmers and bring their adoption               | 0.518| 5.27 |
| C12 | Good climate for developing ASC operations and be safe from natural disasters | 0.503| 4.20 |
| C13 | Tractor and machinery being old and farmers could not be able replace them | 0.479| 5.20 |
| C14 | Maximum distance to other service centers or similar centers             | 0.334| 5.60 |
| C15 | Possibility to extend new crop production in future                      | 0.506| 3.30 |
| C16 | The price of land for cheap extend                                       | 0.838| 3.13 |
| C17 | Easy reach to required labor                                            | 0.569| 4.23 |
| C18 | Enough security                                                          | 0.594| 4.63 |
| C19 | Visibility for farmers                                                  | 0.859| 4.27 |
| C20 | Minimum distance to residential areas                                    | 0.929| 3.00 |
| C21 | Existence of progressive farmers                                         | 0.566| 5.07 |
| C22 | Existence of good educations and tendency to modernism by farmers         | 0.536| 4.70 |
| C23 | Good soil, good climate, less slope, big plot lands, and appropriate wind| 0.516| 5.00 |
| C24 | Existence of crowded population and vast cultivated area                 | 0.316| 6.60 |
| C25 | Minimum distance of villages to each other and large number of them      | 0.472| 5.43 |
| C26 | Maximum number of crop types cultivated                                 | 0.503| 5.47 |
defined, which can minimize the agriculture service costs and consequently product cost. Locations which are near to their customers can reduce their transportation cost, so according to the objective of service cost, location attributes could be selected, which minimized the distance between service centers and the farms/farmers. Time is a critical factor in agricultural commodities, and extremely can influence the quality and price of agricultural production because of being perishable, dependence on whether, etc. The location and also capacity of service centers affects the service time. Therefore the attributes reflects these items can improve the location selection results. Service centers must be sustainable to provide appropriate services to the farms, so their profitability can be considered in this case.

### 3.2. Refinement of attributes by TOPSIS

Attributes were analyzed to refine and reduce their size, and also by selecting the most important ones. If too many factors be included in AHP model, then the number of pairwise comparisons will be increased, so the accuracy of AHP judgments may reduce. Also it is necessary to make them mutually exclusive and nonredundant. So to find five best attributes after the second round Delphi survey, a TOPSIS survey designed to rank ASC attributes, which have highest Delphi score and lowest CV simultaneously. Then they were selected as alternatives in the AHP model to make judgment easy and possible for experts and increase their accuracy. The results of TOPSIS technique are illustrated in Table 5 and Figure 4.

The highest rank ASC attributes has been introduced in Table 6.

### 3.3. Process of the AHP survey

The hierarchy model of ASC location problem formulated and developed as shown in Figure 5.

To find the weight of the ASC location selection attributes, an AHP questionnaire was designed with a 9-point scale and pairwise comparison format. The questionnaire was distributed to 10 agricultural experts. Approximately, 3 of 10 participants had more than 10 years of work experience in agricultural sector and also have related higher academic educations. Other experts almost are professor and PhD student of agricultural engineering. They were asked to make a pairwise comparison judgment and give the relative importance amongst the performance objectives and attributes. The pairwise judgment is conducted from the first level to the third level. Finally, each participant individually expressed their preference between each pair of elements.
Table 5. The results of TOPSIS survey.

| Attribute | Normalized data | Distance to positive ideal solution | Distance to negative ideal solution | Closeness index to ideal solution | Rank |
|-----------|----------------|-------------------------------------|-------------------------------------|-----------------------------------|------|
| C1        | 0.208 0.666    | 0.345                               | 0.116                               | 0.252                             | 23   |
| C2        | 0.055 1.594    | 0.063                               | 0.396                               | 0.863                             | 3    |
| C3        | 0.072 1.240    | 0.160                               | 0.304                               | 0.685                             | 7    |
| C4        | 0.018 1.796    | 0.000                               | 0.458                               | 1.000                             | 1    |
| C5        | 0.110 1.047    | 0.220                               | 0.244                               | 0.526                             | 15   |
| C6        | 0.099 1.047    | 0.218                               | 0.249                               | 0.534                             | 13   |
| C7        | 0.068 1.269    | 0.152                               | 0.313                               | 0.673                             | 6    |
| C8        | 0.035 1.466    | 0.093                               | 0.372                               | 0.800                             | 4    |
| C9        | 0.084 1.212    | 0.170                               | 0.293                               | 0.632                             | 9    |
| C10       | 0.053 1.328    | 0.133                               | 0.332                               | 0.714                             | 5    |
| C11       | 0.096 1.047    | 0.217                               | 0.250                               | 0.535                             | 12   |
| C12       | 0.091 0.666    | 0.321                               | 0.182                               | 0.362                             | 20   |
| C13       | 0.082 1.020    | 0.222                               | 0.251                               | 0.530                             | 14   |
| C14       | 0.040 1.183    | 0.172                               | 0.305                               | 0.639                             | 8    |
| C15       | 0.092 0.411    | 0.391                               | 0.158                               | 0.287                             | 22   |
| C16       | 0.252 0.370    | 0.433                               | 0.042                               | 0.089                             | 25   |
| C17       | 0.116 0.676    | 0.321                               | 0.168                               | 0.343                             | 21   |
| C18       | 0.126 0.810    | 0.287                               | 0.186                               | 0.394                             | 19   |
| C19       | 0.264 0.687    | 0.357                               | 0.102                               | 0.223                             | 24   |
| C20       | 0.309 0.340    | 0.458                               | 0.000                               | 0.000                             | 26   |
| C21       | 0.115 0.969    | 0.242                               | 0.225                               | 0.482                             | 17   |
| C22       | 0.103 0.833    | 0.276                               | 0.203                               | 0.423                             | 18   |
| C23       | 0.096 0.943    | 0.245                               | 0.228                               | 0.482                             | 16   |
| C24       | 0.036 1.644    | 0.045                               | 0.414                               | 0.903                             | 2    |
| C25       | 0.080 1.114    | 0.196                               | 0.272                               | 0.582                             | 11   |
| C26       | 0.091 1.128    | 0.194                               | 0.271                               | 0.582                             | 10   |

Shannon’s weight: 0.726 0.273

Figure 4. The value of closeness index in TOPSIS ranking method.
3.4. FAHP model development

3.4.1. Computing the pairwise comparison matrices of objectives and attributes using fuzzy numbers

By using triangular fuzzy numbers, the fuzzy pairwise comparisons matrix for the main objectives is constructed as follows in Table 7.

First, via pairwise comparison, the fuzzy synthetic extent values of the attributes were calculated in order to assess the priority weights of the main objectives. The values of the fuzzy synthetic extent of the four objectives were denoted $S_{\text{Service Quality}}$, $S_{\text{Service Cost}}$, $S_{\text{Service Speed}}$, and $S_{\text{ASC Profit}}$, respectively:

$$S_{\text{Service Quality}} = \frac{(1.600, 5.661, 19.000) \times (6.169, 16.841, 72.000)}{(0.022, 0.336, 3.080)}$$

$$S_{\text{Service Cost}} = \frac{(1.616, 4.521, 19.000) \times ((6.169, 16.841, 72.000))}{(0.022, 0.268, 3.080)}$$

$$S_{\text{Service Speed}} = \frac{(1.476, 3.233, 18.000) \times ((6.169, 16.841, 72.000))}{(0.021, 0.192, 2.918)}$$

Table 6. The most important attributes based on Delphi survey.

| No. | Attribute                                                                 | New abbreviation            |
|-----|---------------------------------------------------------------------------|-----------------------------|
| C2  | Lack of tractor and machinery                                             | Machinery lack (C1)          |
| C4  | Easy reach to spare parts, repair, customer service center, and gas station| Easy support (C2)           |
| C8  | Easy reach to its villages and covered regions                            | Easy reach (C3)             |
| C10 | Existence of crop rotation with least fallow (irrigated be more than dry farming) | Crop rotation (C4)          |
| C24 | Existence of crowded population and vast cultivated area                  | Population and area (C5)    |
Table 7. Pairwise comparison matrix for objectives.

|     | O1                | O2                | O3                | O4                | Normalized weight |
|-----|-------------------|-------------------|-------------------|-------------------|-------------------|
| O1  | (1.000, 1.000, 1.000) | (0.200, 1.415, 6.000) | (0.200, 1.711, 6.000) | (0.200, 1.533, 6.000) | 0.257             |
| O2  | (0.166, 0.706, 5.000) | (1.000, 1.000, 1.000) | (0.200, 1.245, 7.000) | (0.250, 1.570, 6.000) | 0.252             |
| O3  | (0.166, 0.567, 5.000) | (0.142, 0.785, 5.000) | (1.000, 1.000, 1.000) | (0.166, 0.880, 7.000) | 0.245             |
| O4  | (0.166, 0.652, 5.000) | (0.166, 0.636, 4.000) | (0.142, 1.135, 6.000) | (1.000, 1.000, 1.000) | 0.244             |
| CR  | 0.001             |                   |                   |                   |                   |
| Service quality | C1       | C2       | C3       | C4       | C5       | Normalized weight |
|-----------------|----------|----------|----------|----------|----------|-------------------|
| C1              | (1.000, 1.000, 1.000) | (0.125, 0.322, 4.000) | (0.142, 0.792, 4.000) | (0.142, 1.086, 5.000) | (0.142, 0.569, 5.000) | 0.189             |
| C2              | (0.250, 3.101, 8.000) | (1.000, 1.000, 1.000) | (1.000, 3.282, 8.000) | (1.000, 3.702, 8.000) | (1.000, 2.907, 6.000) | 0.225             |
| C3              | (0.250, 1.261, 7.000) | (0.125, 0.304, 1.000) | (1.000, 1.000, 1.000) | (0.125, 1.584, 5.000) | (0.125, 0.977, 6.000) | 0.195             |
| C4              | (0.200, 0.920, 7.000) | (0.125, 0.270, 1.000) | (0.200, 0.630, 8.000) | (1.000, 1.000, 1.000) | (0.166, 0.812, 3.000) | 0.190             |
| C5              | (0.200, 1.756, 7.000) | (0.166, 0.343, 1.000) | (0.166, 1.022, 8.000) | (0.333, 1.231, 6.000) | (1.000, 1.000, 1.000) | 0.199             |
| CR              | 0.007    |          |          |          |          |                   |
Table 9. Pairwise comparison matrix for service cost.

| Service cost | C1 (1.000, 1.000, 1.000) | C2 (0.142, 0.344, 2.000) | C3 (0.142, 0.468, 3.000) | C4 (0.166, 0.892, 4.000) | C5 (0.200, 0.753, 4.000) | Normalized weight |
|--------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|------------------|
| C1           | (1.000, 1.000, 1.000)    | (0.142, 0.468, 3.000)    | (0.166, 0.892, 4.000)    | (0.200, 0.753, 4.000)    |                          | 0.186            |
| C2           | (0.500, 2.905, 7.000)    | (1.000, 1.000, 1.000)    | (0.142, 1.492, 4.000)    | (0.250, 2.334, 8.000)    | (0.250, 1.614, 6.000)    | 0.214            |
| C3           | (0.333, 2.134, 7.000)    | (0.250, 0.670, 7.000)    | (1.000, 1.000, 1.000)    | (0.333, 1.231, 6.000)    | (0.333, 0.719, 6.000)    | 0.205            |
| C4           | (0.250, 1.120, 6.000)    | (0.125, 0.428, 4.000)    | (0.166, 0.812, 3.000)    | (1.000, 1.000, 1.000)    | (0.166, 0.748, 2.000)    | 0.192            |
| C5           | (0.250, 1.326, 5.000)    | (0.166, 0.619, 4.000)    | (0.166, 1.390, 3.000)    | (0.500, 1.335, 6.000)    | (1.000, 1.000, 1.000)    | 0.200            |
| CR           | 0.01                     |                          |                          |                          |                          |                  |
Table 10. Pairwise comparison matrix for service speed.

| Service speed | C1            | C2            | C3            | C4            | C5            | Normalized weight |
|---------------|---------------|---------------|---------------|---------------|---------------|------------------|
| C1            | (1.000, 1.000, 1.000) | (0.111, 0.455, 3.000) | (0.111, 0.483, 6.000) | (0.200, 1.157, 3.000) | (0.200, 0.950, 4.000) | 0.193             |
| C2            | (0.333, 2.197, 9.000) | (1.000, 1.000, 1.000) | (0.250, 0.821, 9.000) | (0.333, 2.099, 5.000) | (0.250, 1.876, 6.000) | 0.209             |
| C3            | (0.166, 2.069, 9.000) | (0.111, 1.216, 4.000) | (1.000, 1.000, 1.000) | (0.200, 1.586, 9.000) | (0.142, 1.290, 6.000) | 0.207             |
| C4            | (0.333, 0.863, 5.000) | (0.200, 0.476, 3.000) | (0.111, 0.630, 5.000) | (1.000, 1.000, 1.000) | (0.333, 0.835, 2.000) | 0.207             |
| C5            | (0.250, 1.052, 5.000) | (0.166, 0.533, 4.000) | (0.166, 0.774, 7.000) | (0.500, 1.196, 3.000) | (1.000, 1.000, 1.000) | 0.191             |
| CR            | 0.1           |               |               |               |               |                  |
Table 11. Pairwise comparison matrix for ASC profit.

| ASC profit | C1       | C2       | C3       | C4       | C5       | Normalized weight |
|------------|----------|----------|----------|----------|----------|------------------|
| C1         | (1.000, 1.000, 1.000) | (0.200, 1.453, 7.000) | (0.200, 2.065, 7.000) | (0.200, 2.432, 8.000) | (0.166, 1.000, 4.000) | 0.207             |
| C2         | (0.142, 0.688, 5.000) | (1.000, 1.000, 1.000) | (0.200, 1.048, 8.000) | (0.333, 2.334, 6.000) | (0.166, 0.679, 4.000) | 0.201             |
| C3         | (0.142, 0.484, 5.000) | (0.125, 0.954, 5.000) | (1.000, 1.000, 1.000) | (0.250, 1.231, 8.000) | (0.142, 0.357, 5.000) | 0.196             |
| C4         | (0.125, 0.411, 5.000) | (0.166, 0.428, 3.000) | (0.125, 0.812, 4.000) | (1.000, 1.000, 1.000) | (0.166, 0.328, 1.000) | 0.183             |
| C5         | (0.250, 1.000, 6.000) | (0.250, 1.472, 6.000) | (0.200, 2.794, 7.000) | (1.000, 3.047, 6.000) | (1.000, 1.000, 1.000) | 0.210             |
| CR         | 0.1      |          |          |          |          |                  |
\[ S_{\text{AMSC Profit}} = (1.476, 3.424, 16.000) \otimes ((6.169, 16.841, 72.000))^{-1} = (0.021, 0.203, 2.594) \]

The degree of possibility of \( S_i (i \neq j) \) was determined.

\[ V(S_{\text{Service Quality}} \geq S_{\text{Service Cost}}) = 1 \]

\[ V(S_{\text{Service Quality}} \geq S_{\text{Service Speed}}) = 1 \]

\[ V(S_{\text{Service Quality}} \geq S_{\text{AMSC Profit}}) = 1 \]

\[ V(S_{\text{Service Cost}} \geq S_{\text{Service Quality}}) = \frac{3.080 - 0.022}{(3.080 - 0.022) + (0.336 - 0.268)} = 0.978 \]

\[ V(S_{\text{Service Cost}} \geq S_{\text{Service Speed}}) = 1 \]

\[ V(S_{\text{Service Cost}} \geq S_{\text{AMSC Profit}}) = 1 \]

\[ V(S_{\text{Service Speed}} \geq S_{\text{Service Quality}}) = \frac{2.918 - 0.022}{(2.918 - 0.022) + (0.336 - 0.192)} = 0.952 \]

\[ V(S_{\text{Service Speed}} \geq S_{\text{Service Cost}}) = \frac{2.918 - 0.022}{(2.918 - 0.022) + (0.268 - 0.192)} = 0.974 \]

\[ V(S_{\text{Service Speed}} \geq S_{\text{AMSC Profit}}) = \frac{2.918 - 0.021}{(2.918 - 0.021) + (0.203 - 0.192)} = 0.996 \]

\[ V(S_{\text{AMSC Profit}} \geq S_{\text{Service Quality}}) = \frac{2.594 - 0.022}{(2.594 - 0.022) + (0.336 - 0.203)} = 0.950 \]

\[ V(S_{\text{AMSC Profit}} \geq S_{\text{Service Cost}}) = \frac{2.594 - 0.022}{(2.594 - 0.022) + (0.268 - 0.203)} = 0.975 \]

\[ V(S_{\text{AMSC Profit}} \geq S_{\text{Service Speed}}) = 1 \]

The minimum degree of possibility was stated as follows:

\[ \hat{d}(\text{Service Quality}) = \min(1.000, 1.000, 1.000) = 1.000 \]

\[ \hat{d}(\text{Service Cost}) = \min(0.978, 1.000, 1.000) = 0.978 \]

\[ \hat{d}(\text{Service Speed}) = \min(0.952, 0.974, 0.996) = 0.952 \]

\[ \hat{d}(\text{AMSC Profit}) = \min(0.950, 0.975, 1.000) = 0.950 \]

Accordingly, the weight vector was derived as \( \hat{W} = (1.000, 0.978, 0.952, 0.950) \) and the normalized weight was given by \( W = (0.257, 0.252, 0.245, 0.244)^T \). By applying the same calculation process to the remaining attributes, priority weights could be calculated.
From the calculated results listed in Table 7, it can be concluded that, by comparing the weights of objective in Level 2, service quality and service cost are more important than service speed and ASC profit objective.

The local weights of the 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. In this study, all consistency ratios range from 0.001 to 0.1 and overall CR is 0.04, which fell within the acceptance level of 0.10 as recommended by Saaty (1994). This shows that the survey respondents have assigned their weights consistently after examining the priorities of success attributes of location selection for ASCs.

3.4.2. Local weights based on the synthesized judgments

Tables 8–11 hierarchically display local weights according to the Level 3, with the CR using a 5 × 5 matrix. In the Level 3 attributes of service quality, ‘easy support’ (local $W$: 0.225) and ‘population and area’ (local $W$: 0.199) attributes rank first and second, respectively. Also ‘easy reach’ (local $W$: 0.195), ‘crop rotation’ (local $W$: 0.190), and ‘machinery lack’ (local $W$: 0.189) rank the third to fifth, respectively. To visualize this result, Figures 6 and 7 show the local weights of the attributes under service quality and service cost objectives in a radiated diagram.

Similarly from Figures 8 and 9 the priority of attributes under ‘Service Speed’ and ‘ASC Profit’ can be seen.

3.4.3. Global weights based on the synthesized judgments

To determine the overall prioritization of the five attributes with respect to the goal of best location of ASCs, the global weights of the attributes were calculated. Table 12 shows the prioritization of the four objectives and five attributes in terms of the global weights based on the synthesized judgments of evaluators.

From the Level 2 objective weights, we can derive the prioritization of four objectives. Table 12 shows that ‘Service Quality’ (global $W$: 0.257) is most important.
criterion for assessing the ASC location attributes. ‘Service Cost’ (global $W$: 0.252), ‘Service Speed’ (global $W$: 0.245) and ‘ASC Profit’ (global $W$: 0.244) are the second to fifth most important objectives, respectively, in this level.

For Level 3 perspective, the global weight of each attributes was calculated by multiplying the local weight of each attribute under each criterion to global weight of

Figure 7. Radiated diagram of local weight of attributes under service cost objectives.

Figure 8. Radiated diagram of local weight of attributes under service speed objectives.

Figure 9. Radiated diagram of local weight of attributes under ASC profit objectives.
related objectives and calculating sum of them for each attribute. As can be seen in Table 12 the attribute ‘Easy Support’ (global $W$: 0.212) has relatively higher value than other attributes. ‘Population and area’ (global $W$: 0.202) and ‘Easy reach’ (global $W$: 0.201) with less difference are the second and third important attributes. Also ‘Machinery lack’ (global $W$: 0.194) and ‘Crop rotation’ (global $W$: 0.189) are the less important attributes for location selection of ASC.

The attributes selected in this research are interested to use in facility location problem of ASCs. Service centers should be located on places which can reach to their required inputs to provide the services for farms. Easy support attribute means that candidate location is better to have access to fuel stations, agricultural input markets, human workers, etc. The second important attribute is population and area, which directly influence on the service cost and centers profit. Locations which are near to more customers can reduce their costs and get more profits. Accessibility to service centers is almost related to the distance between farmers and centers. But in agricultural areas the accessibility may related to centrality of centers location among villages, because farmers of around areas needed to travel between their farms/home and the center several times in each season. Easy reach to service center will increase the service lead time and center profit. Transportation and also distance are key factors in location problems. Since in this research, we have assumed same priority for objectives, the easy reach ranked third, but if in a situation the service cost and service speed be more important than quality and profit for service centers, then the easy reach will be the most important location attribute, because the transportation directly affect the cost and speed of service. The number of available tractors and machineries in any region can be considered as an attribute, because the service centers should provide mechanization services to the farms which have no machinery or needs some machinery, therefore the centers can be located there. The last attribute is crop rotation which means that service centers can locate on regions that several types of crops are cultivated. Agricultural operations are completely seasonal; it means that some operations in one month of a year are needed and its facilities will remain useless until next season. This phenomenon is not favorable for service centers economically. As our expert team selected the work for the facilities should be available in all times of season. It can be obtained where several crops cultivated in the region.

In this research, we assumed that all objectives have same importance in normal case, but if any manager/researcher want to use this approach with other assumption about objectives and make priority, they are recommended to use the GP method introduced through the paper. They can use some targets/goals for the objectives and

| Objectives | Global $W$ | Prioritizations | Attributes | Global $W$ | Prioritizations |
|------------|------------|----------------|------------|------------|----------------|
| Service quality (O1) | 0.257 | 1 | Easy support (C2) | 0.212 | 1 |
| Service cost (O2) | 0.252 | 2 | Population and area (C5) | 0.202 | 2 |
| Service speed (O3) | 0.245 | 3 | Easy reach (C3) | 0.201 | 3 |
| ASC profit (O4) | 0.244 | 4 | Machinery lack (C1) | 0.194 | 4 |
| Crop rotation (C4) | 0.189 | 5 | | | |
then prioritize the location attributes of service centers. It can be very useful to manage the agricultural systems to be efficient.

4. Conclusions

The main contribution of this paper was to identify the list of objectives and attributes for assessing the best location for establishing ASCs. The paper elaborated upon a hierarchically assessment model and identified important objectives, and their weights to evaluate the relative importance of the ASC location selection problem. This paper contributes to experts by applying the TOPSIS and FAHP model with the Delphi method, which is considered one of the most structured techniques for industrial and managerial decision-making. Based on literature review and Delphi study, a TOPSIS, and an AHP model was generated by incorporating four decision objectives. In addition, the fuzzy approach has been used to make the conventional AHP model more sophisticated with much precise judgment. The results of the FAHP method indicated that agricultural service quality is the most important objective to assess the ASC location attributes. It can be concluded that the service quality is the main expectation from agricultural services. Further, several location attributes are adopted for ASC location and found that support for ASC is the main attribute. Tractors and agricultural machineries have too depreciations because of their working conditions. So these centers need continual repairs both in working season and off-season for next working season. This paper also proposed MCGP to prioritize the objective functions and define targets for them and then rank the attributes based on them. This method can be used to rank ASC location attributes, and this is another contribution of current research, because it is generalizable to other regions and other conditions. The studied problem closely relates to such problems found in manufacturing systems. The proposed methods and the conclusions reached can also be used for solving, e.g. maintenance facility placement problems in manufacturing or supply chain design problems. In future studies, extended research is needed to investigate the effect of current situation of services in agricultural supply chain on priority of location problem objectives in model developed in this paper into a variety of different areas. The main limitation of developed approach is related to the experts participated in this research. Since the methodology used in this paper relies on knowledge and experience of experts, thus it is so critical to use elite experts in such studies.

Acknowledgments

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

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