SELECT A HYPERMARKET LOCATION BASED ON FUZZY MULTI CRITERIA DECISION MAKING (F-MCDM) TECHNIQUES (HYBRID OF F-DELPHI, F-AHP, F-LLSM and F-PROMETHEE)

Hossein Safari
[1]Associated professor of Department of Industrial Management, University of Tehran, Tehran, Iran
[2*]Corresponding Author: Mansour Soufi
Department of Industrial Management, Rasht Branch, Islamic Azad University, Rasht, Iran
Ermia Aghasi
[3]Ph.D student of Department of Industrial Management, University of Tehran, Tehran, Iran

Abstract
The select location of Hypermarket is regarding as the case study in this paper. The proposed hybrid fuzzy MCDM approach is applied to the location choice. There are five criteria and six alternatives (locations) in our model. This paper solves a factor rating system facility location allocation problem defined as follows: 1) Determine alternatives, criteria and decision makers; Define linguistic values and their corresponding fuzzy number and Aggregate the decision-maker's estimation by F-Delphi and F-AHP; 2) Compute the average fuzzy weight and construct the fuzzy decision matrix by F-LLSM and LINGO software; 3) Construct the fuzzy preference function; Define the multi-criteria preference index to decide the valued outranking relation and Calculate the $\widetilde{\Phi}^{+}(a)$, $\widetilde{\Phi}^{-}(a)$ outranking flow and the net flow to pre-order the alternatives by F-PROMETHEE; 4) Defuzzification by the Chen's maxima and minima sets and Ranking of alternatives by Excel.

Keywords: factor rating system facility location allocation problem, F-MCDM, F-Delphi, F-AHP, F-LLSM, F-PROMETHEE.

INTRODUCTION
The success of companies depends on their capability on making right strategic decisions. Facility location selection is one of these strategic decisions, which it is a costly and difficult to reverse activity for companies. Plant location or the facilities location problem is an important strategic level decision making for an organization. One of the key features of a conversion process (manufacturing system) is the efficiency with which the products (services) are transferred to the customers. This fact will include the determination of where to place the plant or facility. The selection of location is a key-decision as large investment is made in building plant and machinery. It is not advisable or not possible to change the location very often. So an improper location of plant may lead to waste of all the investments made in building and machinery, equipment(Anil Kumar and Suresh, 2009). Before a location for a plant is selected, long range forecasts should be made anticipating future needs of the company. The plant location should be based on the company's expansion plan and policy, diversification plan for the products, changing market conditions, the changing sources of raw materials and many other factors that influence the choice of the location decision. The purpose of the location study is to find an optimum location one that will result in the greatest advantage to the organization(Soofi, 2009). While others should get some

credit for earlier work (e.g., Richard Cantillon, Etienne Bonnot de Condillac, David Hume, Sir James D. Steuart, and David Ricardo), it was not until the publication of Johann Heinrich von Thünen's first volume of Der Isolierte Staat in 1826 that location theory can be said to have really gotten underway(Dempsey, 1960). Indeed, the prominent regional scientist Walter Isard has called von Thünen "the father of location theorists "In Der Isolierte Staat, von Thünen notes that the costs of transporting goods consumes some of Ricardo's economic rent. He notes that because these transportation costs and, of course, economic rents, vary across goods, different land uses and use intensities will result with increased distance from the marketplace. However, the discussion was criticized since Johann Heinrich von Thünen oversimplified the problem with his assumptions of, for example, isolated states or single cities (Richards, 2006). This paper proposes an intuitionistic fuzzy multi-criteria decision making method with hybrid of "Fuzzy Analytical Hierarchy Process"(FAHP) pairwise matrix and the weighting expert opinion with "Fuzzy Logarithmic Least Square Method" (F-LLSM); After that, Fuzzy Preference Ranking Organization Method for Enrichment Evaluation (F-PROMETHEE) is utilized to rank the alternatives. Ho (2006) combined the fuzzy set theory and PROMETHEE method developed the Fuzzy PROMETHEE, which is more flexible. The following steps are required for the implementation of the method:

Step1: Determine alternatives, criteria and decision makers;

Step2: Define linguistic values and their corresponding fuzzy number;

Step3: Aggregate the decision-maker’s estimation;

Step4: Compute the average fuzzy weight and construct the fuzzy decision matrix;

Step5: Construct the fuzzy preference function;

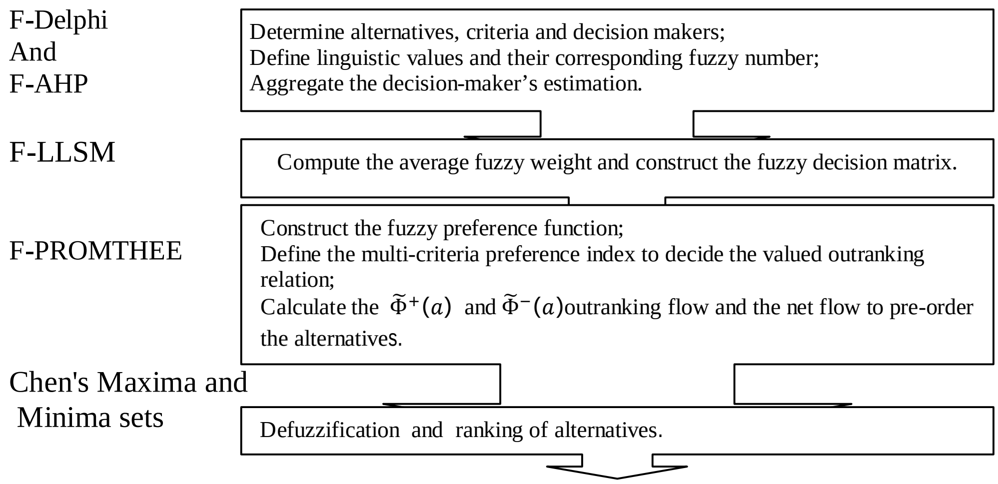
Step6: Define the multi-criteria preference index to decide the valued out ranking relation;

Step7: Calculate the flow to preorder the alternatives (Wang and Chen, 2008).

In this study, the first three steps runs with F-Delphi method for gathering expert's opinion about criteria's values for each location and F-AHP to determine the composed matrix of paired comparisons. The fourth step is performed with F-LLSM in which the criteria weights are determined. Next steps runs with F-PROMETHEE that during which, the weights of alternatives determined then by the Excel are prioritized (Figure 1). The LLSM is a very natural method, and for an AHP with complete information, the solution of LLSM is equivalent to that of the geometric mean method. This of course gives a positive solution, because exponential values obtained by the inverse transformation of logarithm are always positive (Nishizawa & Takahashi, 2009). (Geldermann, Spengler, & RENTZ, 2000) proposed an adaptation of the PROMETHEE method using operations with fuzzy numbers. The weights of the criteria are treated as linguistic variables, represented as triangle fuzzy numbers. In the context of plant location or the facilities location problem in which this paper is included, the performance of alternatives (Location) in each of the criteria can be obtained only at rough. Thus, the use of fuzzy numbers in the evaluation of each alternatives is very adequate and important, since its usage allows a closer look at the reality of the problem, obtaining a more realistic ranking. On the other hand, the impact of alternatives on criteria provided by decision makers is usually difficult to be precisely expressed by the crisp data in the facility location selection(Boran, 2011). An intuitionistic fuzzy set is characterized by three parameters: Membership function, non-membership function and hesitation margin namely, which is a flexible way to deal with uncertainty, while a fuzzy set is only characterized by membership function.

The basis of this paper is organized as follows. In the next section, brief descriptions on intuitionistic fuzzy set are given. Section 3 gives a detailed description of the proposed method. A practical application is given to illustrate the application of the proposed method in Section 4. Finally, conclusions of the paper are presented.

Figure (1): Research design



FACILITY LOCATION PROBLEMS

Facility location problems have occupied an important place in operations research since the early 1960s. They investigate where to physically locate a set of facilities so as to optimize a given function subject to a set of constraints. Facility location models are used in a wide variety of applications. Examples include locating warehouses within a supply chain to minimize the average travel time to the markets, locating hazardous material sites to minimize exposure to the public, locating railroad stations to minimize the variability of delivery schedules, locating automatic teller machines to best serve the bank's customers, and locating a coastal search and rescue station to minimize the maximum response time to maritime accidents (Hale and Moberg, 2003). There are different types of facility location problems. Some basic classes of facility location problems are listed below (Berman and Krass, 2002). *Discrete facility location problem:* location problem where the sets of demand points and potential facility locations are finite. *Continuous facility location problem:* location problem in a general space endowed with some metric, e.g., *lp* norm. Facilities can be located anywhere in the given space. *Network facility location problem:* location problem which is conned to the links and nodes of an underlying network. *Stochastic facility location problem:* location problem where some parameters, e.g. demand or travel time, are uncertain.We can furthermore classify a model as *capacitated* as opposed to *un-capacitated* where the former term refers to the upper bound on the number of clients (or demand) that a facility can serve. Models are called *dynamic* (as opposed to *static*) if the time element is explicitly represented (Wesolowsky, 1973). The problems on which we focus our attention in this paper can be characterized as discrete, deterministic, un capacitated, and static network models. Current *et al.* (2002) listed several basic discrete network location models: covering (including set-covering and maximal covering), *p*-center, *p*-dispersion, *p*-median, fixed charge, hub, and maximal. Distances or some related measures (e.g., travel time or cost) are fundamental to such problems. Consequently, we classify them according to their consideration of distance. The first four are based on maximum distance and the last four are based on total (or average) distance. In this paper, we discuss problems related to the *p*-median and covering problems.

As Marianov and Serra (2002) pointed out, both the *p*-median and covering problems can be considered benchmarks in the development of facility location models. While the *p*-center problem is also an important location model, the location set covering problem can be used as a sub-problem in solving the classical *p*-center problem (Handler and Mirchandani, 1979; Handler, 1990). Daskin (2000) showed how the maximal covering model can be used effectively in place of the location set covering model as a sub-problem in solving the un-weighted vertex *p*-center problem.

THE P-MEDIAN PROBLEMS

The *p*-median problem belongs to a class of formulations called mini-sum location models. The problem can be stated as find the location of a fixed number of p facilities so as to minimize the weighted average distance of the system. The first explicit formulation of the *p*-median problem is attributed to Hakimi (1964). Hakimi not only stated the formulation of the problem, but also proved that in a connected network optimal locations can always be found on nodes. Consequently, it is only necessary to consider the nodes of the network as potential locations. Goldman (1971) provided simple algorithms for locating a single facility for both an acyclic network (a tree) and a network containing exactly one cycle. The *p*-median problem on a plane (continuous feasible space) is also known as the Weber problem. We refer the reader to Drezner *et al.* (2002) for a detailed discussion of the Weber problem. For the polynomial time algorithm of the *p* median problem on a tree network, the interested reader is directed to Kariv and Hakimi (1979). For a discussion of formulations and solution approaches of the *p*-median problem, we refer the readers to Mirchandani (1990). Recently, Marionov and Serra (2002) gave a state-of-the-art review of the *p*-median problem and its extensions.

COVERING PROBLEMS

Unlike the *p* median problem which seeks to minimize the weighted travel distance, covering Models are based on the concept of acceptable proximity. A customer is considered covered, if she has a facility sited within a preset distance. Covering models can be classified according to several criteria. One of such criteria is the type of objective, which allows us to distinguish between two types of formulations. The first type belongs to the Location Set Covering Problem (LSCP), which seeks to find the minimum number of facilities that cover all customers' demand. This problem was originally stated in Toregas *et al.* (1971). The second type can be classified as the Maximal Covering Location Problem (MCLP), which maximizes covered customer demand, given a limited number of facilities. The MCLP was first introduced in Church and Revelle (1974). Church and Meadows (1979) provided a Pseudo - Hakimi property for the MCLP. This property states that for any network, there exists a finite set of points that will contain at least one of the optimal solutions to the MCLP. Daskin and Stern (1981), Hogan and Revelle (1986), and Batta and Mannur (1990) developed the MCLP that contains a secondary "backup" coverage objective. Berman and Krass (2002) showed that the MCLP with a step coverage function is equivalent to the uncapacitated facility location problem (Cornuejols et al, 1990). They developed two IP formulations for the problem and showed an interesting result that the LP relaxations of both formulations provide the same value of the upper bound. In a recent paper, Berman *et al*. (2003) investigated the MCLP with a coverage decay function whose value decreases from full coverage at the lowest pre-specified radius to no coverage at the highest pre-specified radius. Daskin (1983) provided a probabilistic formulation of the problem in which the probability of an arbitrary server being busy is specified exogenously. The objective, then, is to locate facilities so as to maximize the expected number of demand that a facility can cover. Daskin's formulation is sometimes referred to as the Maximal Expected Covering Location Problem.

A review of covering models and their applications can be found in Revelle and Williams (2002).

FACTOR RATING SYSTEMS

The problem of facility location is faced by both new and existing businesses. Criteria that influence facility location include proximity to customers, business climate, total costs, availability and quality of infrastructure, quality of labor, suppliers, other available facilities, free trade zones, political risk, government barriers, trading blocs, environmental regulations, the host community and finally competitive advantage. Factor-rating systems are the most widely used location techniques as they combine diverse factors in an easy-to-understand format. The transportation method is a special linear programming method while the center of gravity methods is another popular location solution method that focuses on minimizing shipping costs and distances. While it is usually less expensive to establish a service facility than a manufacturing facility, service facilities have unique issues to consider. When choosing a location for a service facility it is important to maintain close contact with the customer. Frequently, regression models are used to assist with site selection. The criteria for selecting appropriate locations have evolved beyond the singular focus on minimizing cost or distance. Today a number of quantitative and qualitative issues impact location decisions. A company's long-term success depends on its managers' ability to make a comprehensive synthesis of the various dimensions of the multifaceted location problem (Richard, B.et al,2006). Factor-rating systems are perhaps the most widely used of the general location techniques because they provide a mechanism to combine diverse factors in an easy-to-understand format. By way of example, an industrial corporation assigned the following range of point values to major factors affecting a set of possible sites:

Table (1): Range of point values to major factors affecting a set of possible sites

FACTORS	RANGE
Fuels in region	0 to 330
Power availability and reliability	0 to 200
Labor climate	0 to 100
Living conditions	0 to 100
Transportation	0 to 50
Water supply	0 to 10
Climate	0 to 50
Supplies	0 to 60
Tax policies and laws	0 to 20

Each site was then rated against each factor, and a point value was selected from its assigned range. The sums of assigned points for each site were then compared. The site with the most points was selected. A major problem with simple point-rating schemes is that they do not account for the wide range of costs that may occur within each factor. For example, there may be only a few hundred dollars’ difference between the best and worst locations on one factor and several thousands of dollars’ difference between the best and the worst on another. The first factor may have the most points available to it but provide little help in making the location decision; the second may have few points available but potentially show a real difference in the value of locations. To deal with this problem, it has been suggested that points possible for each factor be derived using a weighting scale based on standard deviations of costs rather than simply total cost amounts. In this way, relative costs can be considered.

LITERATURE REVIEW

The study of location theory problems literature that examples of them is given in Table 2; demonstrate the use of multi-criteria decision making techniques in solving this type of problem, the early 21st century has begun. As mentioned, the location problems such as the P-Median and Covering problems, are used the quantitative variables such as cost and distance for optimal location but in Factor Rating System (FRS) problem are used qualitative variable such as efficiency, customer satisfaction, access and etc. To solve these types of problems normally, has been used expected of weighted sum of the criteria and the alternative has the most points is the priority. The increased sensitivity of the facilities, as well as increased losses resulting from wrong location. That's why facilities owners and managers need to use a more accurate method was to deploy their facilities. However, the study of the techniques employed in Table 2 shows that we are still in the early stages and the taste of them, because each one has its own weaknesses. These weaknesses with the strengths of other techniques are covered. Therefore, this study uses fuzzy logic and the most powerful algorithms are used for selection criteria and the alternatives to weighted, aggregated paired comparisons matrix and finally prioritize alternatives by hybrid MCDM techniques.

Table (2): Literature review about using MCDM techniques for Location problems

Author	Year	Method	Subject
JP Brans, P Vincke	1985	PROMETHEE	A preference ranking organization method: the PROMETHEE method for MCDM
Ishikawa et al.	1993	Fuzzy Delphi (FDM)	An Application of Fuzzy Delphi and Fuzzy AHP on Evaluating Wafer Supplier in Semiconductor Industry
Noorderhaben	1995	FDM	Applying the Fuzzy Delphi Method to group decision can solve the fuzziness of common understanding of expert opinions.
Klir and Yuan	1995	FDM	Fuzzy sets and fuzzy logic – Theory and application
M. Goumas, V. Lygerou	2000	PROMETHEE	Extension of the PROMETHEE method for decision making in fuzzy environment: Ranking of alternative energy exploitation projects
Cheung, Kuen, and Skitmore	2002	AHP	Implemented analytic hierarchy process (AHP) for the architectural consultant selection for the design and construction of the projects in Hong Kong.
Chen Tung Chen, Sue Fen Huang	2007	Fuzzy method	Applying fuzzy method for measuring criticality in project network
Tabari et.al	2008	Fuzzy AHP	Select the optimal location that satisfies the decision maker
Önüt and Soner	2008	Fuzzy TOPSIS	Solid waste transshipment site selection problem in Istanbul, Turkey
Dağdeviren and Erarslan	2008	PROMETHEE	Select the most appropriate supplier
Tuzkaya	2009	Fuzzy AHP	Chose the environmentally convenient transportation mode
Chen-Tung Chen et.al	2009	PROMETHEE	Applying multiple linguistic PROMETHEE method for personnel evaluation and selection
D. Aloini, R. Dulmin, V. Mininno	2009	Fuzzy PROMETHEE	A Hybrid Fuzzy-Promethee Method for Logistic Service Selection: Design of a Decision Support Tool
Kayikci	2010	Fuzzy AHP & ANN	Select the most appropriate location
Kuo	2010	Fuzzy DEMATEL	Optimal international distribution center location selection
Wan Zhengtian, Wang Min, Wang Lizheng	2010	Fuzzy Matter Element Method	Applying fuzzy matter-element method to evaluating the green degree of ship

E. Ocelikova, D. Klimesova	2010	PROMETHEE	Using PROMETHEE method for the ranking of multidimensional data
Özcan et.al	2011	Compared AHP, TOPSIS, ELECTRE and Grey Theory	Warehouse location selection problem
Ying Hsiu Chen, Tien Chin Wang, Chao Yen Wu	2011	Fuzzy PROMETHEE	Strategic decisions using the fuzzy PROMETHEE for IS outsourcing
Awasti et.al	2011	fuzzy TOPSIS	location for implementing an urban distribution center
Chen et.al	2011	fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS	A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers
Mohammad Ali Shafia et.al	2011	Fuzzy balanced scorecard	Applying fuzzy balanced scorecard (BSC) for evaluating the CRM performance
Chen-Tung Chen et.al	2011	PROMETHEE	APPLYING LINGUISTIC PROMETHEE METHOD IN INVESTMENT PORTFOLIO DECISION-MAKING

FUZZY DELPHI

The Delphi approach uses expert opinion surveys with three special features: anonymous response, iteration and controlled feedback, and statistical group response. The number of iterations of Delphi questionnaires may vary from three to five, depending on the degree of agreement and the amount of additional information being sought or obtained. Generally, the first questionnaire asks individuals to respond to a broad question. Each subsequent questionnaire is built upon responses to the preceding questionnaire. The process stops when consensus has been approached among participants, or when sufficient information exchange has been obtained. Thus, one of the most attractive properties of this approach is the ability to gather and evaluate information from a group of experts without requiring a face-to-face meeting.

The Delphi approach typically involves three different groups: decision-makers, staff, and experts (Hwang and Lin, 1987). Decision-makers are responsible for the outcome of the Delphi study. A work
group of five to nine members, composed of both staff and decision-makers, develops and analyzes all
questionnaires, evaluates collected data, and revises the questionnaires if necessary. The staff group is
directed by a coordinator who should have experience in designing and conducting the Delphi method
and is familiar with the problem area. The staff coordinator's duties also involve supervising a support
staff in typing, mailing questionnaires, receiving and processing results, and scheduling meetings. Respondents are recognized as experts on the problem. The Delphi method is suitable for decision domains:

- Where expertise is subjective and inputs likely to be judgmental
- Where problems are large, complex, and multidisciplinary and considerable uncertainties exist
- Where there is the possibility of unexpected breakthroughs
- Where causal models cannot be built or validated
- Where time frames are particularly long
- Where opinions are required from a large group, and anonymity is preferred

One of the weaknesses of the Delphi method is that it requires repetitive surveys of the experts to allow the evaluations to converge. The cost of this method rapidly increases with repetitive surveys, especially in large and complicated problems (Ishikawa, 1993). The fuzzy Delphi method is applied to alleviate this problem. Using fuzzy numbers or linguistic labels for evaluating the experts' opinions allows a faster convergence to an agreeable group decision. An example presented in Cheng (1999) uses linguistic terms to express the experts' responses.

In this study, the fuzzy Delphi method was used to collect the opinions of experts.

FUZZY ANALYTIC HIERACHY PROCESS (Fuzzy AHP)

In some instances, decision problems are hard to conceptualize or even clearly define. The AHP was formulated to support the decision-maker in these situations.

Analytical Hierarchical Process is based on the following two steps:

1. structuring the decision as a hierarchical model,
2. using pairwise comparison of all criteria and alternatives to find the calculated weight of the criteria and the score of each alternative.

AHP allows decision-makers to examine complex problems in a detailed rational manner. The hierarchical representation helps in dealing with large systems, which are usually complex in nature. The decisions are made one level at a time, from the bottom-up, to more clearly aggregate strategic levels. The advantages of AHP include highly structured and more easily understood models and consistent decision-making .The disadvantages of AHP arise mainly from the decision-maker, who has to make many pairwise comparisons to reach a decision while possibly using subjective preferences. The fuzzy AHP approach uses the concepts of fuzzy set theory for evaluation of alternatives and defining the weights of criteria. Shamsuzzaman et al. (2003) integrated fuzzy sets and the AHP for selecting the best-ranked flexible manufacturing system from a number of feasible alternatives. Fuzzy sets are employed to recognize the selection criteria as linguistic variables rather than numerical ones. The AHP is used to determine the weights of the selection criteria in accordance with their relative importance. Despite of its wide application to various decision-making problems, the conventional AHP approach may not fully reflect a style of human thinking. Thus, the fuzzy AHP approach is proposed to overcome the disadvantage of the conventional AHP. The fuzzy AHP approach is a systematic method for the alternative choice and justification problems that combines the concept of fuzzy sets theory (Zadeh,1965) and the hierarchical structure analysis (Saaty,1980). Fuzzy AHP approach has been widely applied to many decision-making problems. For example, Chang (1996) developed a fuzzy extent analysis for AHP and the approach is relatively easier in computational procedure than the other fuzzy AHP approaches. Kuo et al. (1999) presented a fuzzy AHP method for the location choice of a convenience store. Kurttila et al.(2000) combined AHP with SWOT to provide a new hybrid method for a forest certification case. Stewart et al. (2002) combined AHP method with SWOT to present a new approach for improving the usability of AHP in strategic management. Kahraman et al. (2003) applied fuzzy AHP to select the location of facility. Zhang et al. (2005) combined fuzzy AHP with MCDM to deal with an MCDM decision-making problem.The results show that the proposed hybrid method was a useful way to deal with MCDM decision making problems. Erensal et al. (2006) determined key capabilities in technology management by using fuzzy AHP. Chan and Kumar (2007) proposed a model for global supplier development considering risk factors by using fuzzy AHP. Bozbura and Beskese (2007) determined the priorities of organizational capital measurement indicators by using fuzzy AHP. Bozbura et al. (2007) used fuzzy AHP method to determine the priorities of human capital measurement indicators. Lee and Lin (2008) developed a fuzzy quantified

SWOT procedure that integrates MCDM concept and fuzzy AHP method for the location choice of international distribution centers.
In this study, for create paired comparison matrix in the different steps, the F-AHP is used.

FUZZY LOGARITHMIC LEAST SQUARE METHOD

In Multi Criteria Decision Making (MCDM) methods, the ratings and the weights of the criteria are known precisely. However, crisp data are inadequate to model real-life situations, since human judgments including preferences are often vague and one's preference cannot be estimated with an exact numerical value. A more realistic approach may be to use linguistic variables like high, very high, etc. instead of numerical values. A natural way to cope up with such uncertain judgments is to express the comparison ratios as fuzzy sets or fuzzy numbers which incorporate the vagueness of human thinking. When comparing any linguistic variables, the uncertain comparison judgment can be represented by membership functions or the fuzzy number. Here, linguistic values expressed as trapezoidal fuzzy numbers are used to assess the priority of the factors. The fuzzy logarithmic least square method (LLSM) developed by Wang et al.(2011) is employed to obtain the vector of triangle fuzzy weights through the optimization model of fuzzy LLSM using fuzzy pair wise comparison matrices.
Logic AHP technique is based on the assumption that the scale matrix of paired comparisons a paired comparison matrix is consistent. Paired comparison matrix is completely consistent if it can be written:

$$a_{ik} \times a_{kj} = a_{ij} \qquad (1)$$

Then:

$$a_{ij} = \frac{W_i}{W_j}$$

$$a_{ij}.W_j - W_i = e = 0 \qquad (2)$$

In practical environment, the assumption of perfect consistency, the assumption seems to be ideal. Hence, we seek to minimize the error (e) are. The method of least squares, we know the least error, instead of the second moment of total errors occur namely:

$$Min\ e = \sum_{i=1}^{n}\sum_{j=1}^{n}(a_{ij}.W_j - W_i)^2$$

S.T: $\sum_{i=1}^{n} W_i = 1 \quad W_i \geq 0\,; j, i = 1,2,\dots,n$

Based on the logarithmic least squares method, minimum error occurs as follows:

$$\text{Min e} = \sum_{i=1}^{n}\sum_{j=1}^{n}(\log a_{ij} - \log(\frac{W_i}{W_j}))^2 \qquad (3)$$

S.T: $\sum_{i=1}^{n} W_i = 1 \quad W_i \geq 0\,; j, i = 1,2,\dots,n$

For weight extraction of fuzzy paired comparisons, there are two types of methods. The first type are some of the weights obtained in the form of real numbers such methods, FPP (Mikhailov, 2003) and LFPP (Wang & Chin, 2011). The Second type are the methods in which the weights are obtained as fuzzy numbers. Methods such as, LAMBDA-Max (Wang et al, 2006), a linear goal programming method (Wang & Chin, 2008) and Fuzzy logarithmic least squares method (F-LLSM) (Wang & Chin, 2010) are of this type.
Fuzzy logarithmic least squares method (F-LLSM) is capable of a paired comparison matrix (Table 3) to derive weights for solving nonlinear programming with the work that is given.

$$Min\ J = \sum_{i=1}^{6}\sum_{j=1,i\neq j}^{6}\sum_{k=1}^{5}\begin{pmatrix}\left(ln\,w_i^L - ln\,w_j^U - ln\,a_{ijk}^L\right)^2 + \left(ln\,w_i^M - ln\,w_j^M - ln\,a_{ijk}^M\right)^2 \\ +\left(ln\,w_i^U - ln\,w_j^L - ln\,a_{ijk}^U\right)^2\end{pmatrix}$$

(4)

$$\boldsymbol{S}ubject\ to\begin{Bmatrix} w_i^L + \sum_{j=1,i\neq j}^{n} w_j^U \geq 1 \\ w_i^U + \sum_{j=1,i\neq j}^{n} w_j^L \leq 1 \\ \sum_{i=1}^{n} w_i^M = 1 \\ \sum_{i=1}^{n}\left(w_i^L + w_i^U\right) = 2 \\ w_j^U \geq w_j^M \geq w_j^L \geq 0, i = 1, \dots, n \end{Bmatrix}$$

Constraints that have been added on Fuzzy method, normalized the output fuzzy weights.

Table (3): fuzzy group pairwise comparison

Criteria	Criteria 1	Criteria 2	…	Criteria n
Criteria 1			…	
Criteria 2			…	
⋮	⋮	⋮	⋮	⋮
Criteria n			…	

FUZZY PROMETHEE

Adaptations of the PROMETHEE method to use fuzzy numbers in the evaluations of alternatives, as used in this work, are presented below:

1. Set of alternatives (A_i), criteria (C_j) and decision makers.
2. Determine the linguistic variable and their fuzzy numbers (like table 5 and table 6).
3. The estimated aggregate decision makers. Preference weight average of each criterion is:

   $$\widetilde{W}_j = \frac{1}{n}\left[\sum_{e=1}^{n}\widetilde{W}_j^e\right] = \frac{1}{n}\left[\widetilde{W}_j^1 \oplus \widetilde{W}_j^2 \oplus \dots \oplus \widetilde{W}_j^n\right] \qquad (5)$$

   The assessed value of alternative i (A_i) based on criterion j (C_j) is equal to:

   $$\tilde{X}_{ij} = \frac{1}{n}\left[\sum_{e=1}^{n}\tilde{X}_{ij}^e\right] = \frac{1}{n}\left[\tilde{X}_{ij}^1 \oplus \tilde{X}_{ij}^2 \oplus \dots \oplus \tilde{X}_{ij}^n\right] \qquad (6)$$

4. Determine the fuzzy weighted average and create a fuzzy decision matrix.
5. Create a fuzzy preference function.

In this study assuming the evaluations of alternatives under a given criterion j as triangular fuzzy number (m,α,β), the difference distance *(a ,b)* between the evaluations of two alternatives *a and b*, represented as a rating of (Dubois and Prade, 1978). Knowing that the choice, done by the decision maker, of the function of preference to be used in each criterion depends on the type of problem, one can consider that, in most cases, the type II preference function (with partial criteria indifference) is one of the most adequate (Brans et al,1986). If A is a set of alternatives and (*a and b*) are two alternatives to this collection, the preferred function can be defined as follows (The general criterion type II can be expressed as (Dupont, 2003):

$$P(d) = \begin{cases} 0 & d \le q \\ 1 & d > q \end{cases} \qquad (7)$$

Preference function [($\widetilde{P}\,(a,b)$] represents the intensity of the Premier, namely the (*a to b)* is preferred. Preference function is obtained by examining pairwise comparison below:

$$\begin{cases} \tilde{X}_{aj} > \tilde{X}_{bj} \Longleftrightarrow & aPb \; (a \text{ outranks } b) \\ \tilde{X}_{aj} = \tilde{X}_{bj} \Longleftrightarrow & aIb \; (a \text{ is indifferent to } b) \end{cases} \qquad (8)$$

6. The degree of preference comparison of the alternatives *a and b*, with the criterion f, can be defined as:

   $P_j\,[\tilde{f}(a) - \tilde{f}(b)] = P_j\,(\tilde{d}) = P_j[(m,\alpha,\beta)_{LR}] = [P_j\,(m), [P_j\,(m) – P_j\,(m-\alpha)], [P_j\,(m+\beta) - P_j\,(m)]]$ (9)

7. Definition of multi-criteria preference list in order to determine the relationship between measured preference index with:

   When weights of criteria is equal: $\tilde{\pi}(a, b) = \frac{1}{k}\sum_{j=1}^{k} \tilde{P}_j\,(a, b)$ (10)

   In otherwise: $\tilde{\pi}(a, b) = \frac{\sum_{j=1}^{k} W_j\,\tilde{P}j\,(a,b)}{\sum_{j=1}^{k} W_j}$ (11)

8. Flow calculation for pre-ordering alternatives. The leaving flow and entering flow will be fuzzy numbers according to equations (12) and (13), respectively.

$$\tilde{\Phi}^{+}(a) = \frac{\sum_{\substack{b=1 \\ b\neq a}}^{n} \tilde{\pi}(a,b)}{n-1} \qquad (12)$$

$$\tilde{\Phi}^{-}(a) = \frac{\sum_{\substack{b=1 \\ b\neq a}}^{n} \tilde{\pi}(a,b)}{n-1} \qquad (13)$$

9. The net flow is also a fuzzy number obtained through the difference between leaving and entering flows.

$$\tilde{\Phi}(a)\;(a) = \tilde{\Phi}^{+}(a) - \tilde{\Phi}^{-}(a) \quad (14)$$

Finally, the ranking of alternatives must be done. The results are presented in the form of fuzzy numbers and the main problem in this step is the comparison of fuzzy numbers. There

are several models proposed for ranking fuzzy numbers. In this study a proposal is made that the net flow be defuzzified by the Chen's maxima and minima according to equation below:
Maxima sets for R = $\{[X, f_R(X)] | X \in R\}$ and

$$f_R(X) = \begin{cases} \frac{(X-X_1)}{(X_2-X_1)}, X_1 \leq X \leq X_2 \\ 0, otherwise \end{cases} \quad (15)$$

Maxima sets for L = $\{[X, f_L(X)] | X \in R\}$ and

$$f_L(X) = \begin{cases} \frac{(X-X_1)}{(X_2-X_1)}, X_1 \leq X \leq X_2 \\ 0, otherwise \end{cases} \quad (16)$$

A Case Study

The select location of Hypermarket is regarding as the case study in this paper. In this section, the proposed hybrid fuzzy MCDM approach is applied to the location choice of Hypermarket for a cooperative in Rasht, IRAN.
There are five criteria and six alternatives (locations) in our model and they are as follows (Table 4):

Table (4): Criteria for location selection

Criteria	Definition
Accessibility (C1)	Access by public and private transport modes to the location
Security (C2)	Security of the location from accidents, theft and vandalism
Connectivity to multimodal transport (C3)	Connectivity of the location with other modes of transport, e.g. highways, railways, seaport, airport etc.
Proximity to customers (C4)	Distance of location to customer locations
Proximity to suppliers (C5)	Distance of location to supplier locations

Step 1: F-DELPHI

Selection of location criteria

Step 1 involves the selection of location criteria for evaluating potential locations for hypermarket centers. These criteria are obtained from literature review, and discussion with experts. Five important criteria are finally chosen to determine the best location for implementing hypermarket center. These criteria are shown in Table (4).
The remaining criteria are benefit type criteria, that means the higher the value, the more preferable the alternative for the best location.

Selection of potential locations

The decision makers use their knowledge, prior experience with the hypermarket conditions of the city and the presence of sustainable freight regulations in the city to identify candidate locations for implementing hyper market center. For example, if certain areas are restricted for delivery by municipal administration, then these areas are barred from being considered as potential locations for implementing the center. Ideally, the potential locations are those that cater to the interest of
all citizenship, that is city residents, logistics operators, municipal administrations etc.

Use the F-Delphi with Linguistic variables

In this study, the fuzzy Delphi method was used to collect the opinions of experts. The five Linguistic variables questionnaires were distributed among five experts in several stages. These experts include IRONI Big Store with two branches, SENATOR Big Store, DOLPHIN Big Store, City Mall shopping center and City Hypermarket. In fuzzy set theory, conversion scales are applied to transform the linguistic terms into fuzzy numbers.

Step 2: F-AHP

Provide fuzzy total pairwise comparisons matrix of criteria

In this paper we assume there are J possible candidates called L = {L1, L2, to L_j} and *m* criteria, C = {C1, C2 to C_m}. The criteria weights are denoted by W_i (i = 1, 2, to m). The performance ratings of each decision maker D_k (k = 1, 2, to K) for each alternative A_j (j = 1, 2, to n) with respect to criteria C_i (i = 1, 2, to m) are denoted by $\widetilde{R}_K = \widetilde{X}_{ijk}$ (i = 1, 2, . . . ,m; j = 1, 2, . . . , n; k = 1, 2, . . . , K) with membership function $\mu\widetilde{R}_K$ (x).

Compute the fuzzy decision matrix

The fuzzy decision matrix for the alternatives ($\widetilde{D}$) and the criteria ($\widetilde{W}$) is constructed as follows:

$$\tilde{D} = \begin{matrix} & C_1 & C_2 & & C_n \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{matrix} \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn} \end{bmatrix}, \quad i = 1, 2, \dots, m;\ j = 1, 2, \dots, n \qquad (13)$$

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n).$$

After recognize the decision-makers in problem, Used the Linguistic variables (like table6) to obtain the decision matrix of criteria for these decision-makers (like table7).

In this paper, we will apply a scale of [0 – 1] for rating the criteria and the alternatives. Table (5) presents the linguistic variables and fuzzy ratings for the alternatives and criteria and table (6) show the linguistic variables for Person (1) in the case. Table (7) presents the triangular fuzzy numbers based on table (5).

Table (5): Linguistic variables for Decision Matrix

linguistic variables	triangular fuzzy numbers		
very low	0.00	0.00	0.20
low	0.10	0.20	0.30
medium low	0.20	0.35	0.50
medium	0.40	0.50	0.60
medium high	0.50	0.65	0.80
high	0.70	0.80	0.90
very high	0.80	1.00	1.00

Table (6): Linguistic variables for decision- maker (1)

Ranking of Location	Accessibility	Security	Connectivity transport	Proximity to customers	Proximity to suppliers
Location 1	L	VL	L	M	M
Location 2	ML	MH	VL	L	L

Location 3	H	VH	H	M	M
Location 4	H	M	MH	L	VL
Location 5	M	MH	M	L	VL
Location 6	H	ML	H	L	VL

Table (7): Fuzzy Decision Matrix for decision-maker (1)

Ranking of Location	Criteria 1			Criteria 2			Criteria 3			Criteria 4			Criteria 5		
Location 1	0.1	0.2	0.3	0	0	0.2	0.1	0.2	0.3	0.4	0.5	0.6	0.4	0.5	0.6
Location 2	0.2	0.35	0.5	0.5	0.65	0.8	0	0	0.2	0.1	0.2	0.3	0.1	0.2	0.3
Location 3	0.7	0.8	0.9	0.8	0.9	1	0.7	0.8	0.9	0.4	0.5	0.6	0.4	0.5	0.6
Location 4	0.7	0.8	0.9	0.4	0.5	0.6	0.5	0.65	0.8	0.1	0.2	0.3	0	0	0.2
Location 5	0.4	0.5	0.6	0.5	0.65	0.8	0.4	0.5	0.6	0.1	0.2	0.3	0	0	0.2
Location 6	0.7	0.8	0.9	0.2	0.35	0.5	0.7	0.8	0.9	0.1	0.2	0.3	0	0	0.2

Step 3: F-LLSM

To calculate weights of criteria, F-LLSM and LINGO software is used. After collect the data of each alternative, to quantitative linguistic variables, the researcher can use table (8) to obtain the fuzzy pairwise comparisons matrix (table 9) for used F-LLSM to obtain criteria's weights.

Table (8): Linguistic variables for Fuzzy group pairwise comparisons matrix

linguistic variables	**triangular fuzzy numbers**		
very poor	0.00	0.00	2.00
poor	1.00	2.00	3.00
medium poor	2.00	3.50	5.00
medium	4.00	5.00	6.00
medium good	5.00	6.50	8.00
good	7.00	8.00	9.00
very good	8.00	10.00	10.00

Table (9): Fuzzy group pairwise comparisons matrix for criteria

Location Problem	C_1	C_2	…	C_5
C1	(1,1,1)	$\begin{Bmatrix} (1,2,3) \\ \ldots \\ (0.33,0.5,1) \end{Bmatrix}$	…	$\begin{Bmatrix} (2,3,4) \\ \ldots \\ (3,4,5) \end{Bmatrix}$
C2	$\begin{Bmatrix} (0.33,0.5,1) \\ \ldots \\ (1,2,3) \end{Bmatrix}$	(1,1,1)	…	$\begin{Bmatrix} (1,2,3) \\ \ldots \\ (4,5,6) \end{Bmatrix}$
⋮	⋮	⋮	⋮	⋮
C5	$\begin{Bmatrix} (0.25,0.33,0.5) \\ \ldots \\ (0.2,0.25,,0.33) \end{Bmatrix}$	$\begin{Bmatrix} (0.33,0.5,1) \\ \ldots \\ (0.17,0.2,0.25) \end{Bmatrix}$	…	(1,1,1)

As a result, the following weights were obtained for decision-maker (1).

Table (10): Weights of Criteria for DM1with F-LLSM by LINGO

	Criteria 1			Criteria 2			Criteria 3			Criteria 4			Criteria 5		
Variable	W_{11}	W_{12}	W13	W_{21}	W_{22}	W_{23}	W_{31}	W_{32}	W_{33}	W_{41}	W_{42}	W_{43}	W_{51}	W_{52}	W_{53}
Value	0.22	.27	0,31	0.25	0.31	o.36	0.13	0.17	0.22	0.68	0.78	0.0.96	0.08	0.09	0.10

Step 3: F-PROMETHEE

Steps one to four of fuzzy PROMETHEE were obtained with F-DELPHI, F-AHP and F-LLSM techniques. Other phases of the case are as follows:
The decision matrix for all five experts to case study is aggregated in Table 11.

Table (11): Fuzzy Aggregated Decision Matrix

Aggregated Decision Matrix	C 1			C 2			C 3			C 4			C 5		
A 1	0.534	0.634	0.734	0.155	0.228	0.355	0.179	0.266	0.379	0.428	0.548	0.669	0.414	0.521	0.628
A 2	0.228	0.371	0.514	0.300	0.395	0.559	0.048	0.088	0.266	0.169	0.278	0.386	0.348	0.448	0.548
A 3	0.717	0.817	0.917	0.721	0.829	0.938	0.686	0.790	0.893	0.400	0.500	0.600	0.483	0.590	0.697
A 4	0.569	0.671	0.786	0.348	0.448	0.548	0.393	0.516	0.638	0.438	0.553	0.669	0.303	0.369	0.524
A 5	0.400	0.500	0.600	0.472	0.614	0.755	0.459	0.567	0.676	0.266	0.386	0.507	0.262	0.338	0.497
A 6	0.466	0.593	0.721	0.286	0.428	0.569	0.576	0.679	0.783	0.252	0.360	0.469	0.200	0.255	0.400
Weight	0.090	0.172	0.303	0.293	0.417	0.541	0.469	0.583	0.697	0.466	0.591	0.717	0.631	0.724	0.831

For each criterion (C_j), a square preference matrix (P_i) is formed that in its, preferred alternative compared to any other alternatives (P_{ij}) to C_j specified. For example table 12 calculated for C1.

Table (12): Fuzzy Preference matrix for Accessibility (C1)

P1	A1			A2			A 3			A 4			A 5			A 6		
A 1	0.00	0.00	0.00	-0.20	0.26	0.51	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	0.13	0.33	-0.19	0.04	0.27
A 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A 3	-0.02	0.18	0.38	-0.02	0.45	0.69	0.00	0.00	0.00	-0.07	0.15	0.35	0.12	0.32	0.52	0.00	0.22	0.45
A 4	-0.17	0.04	0.25	-0.17	0.30	0.56	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.17	0.39	-0.15	0.08	0.32
A 5	0.00	0.00	0.00	-0.33	0.13	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A6	0.00	0.00	0.00	-0.27	0.22	0.49	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.09	0.32	0.00	0.00	0.00

Then, the total preference matrix (π) is calculated. In this matrix, the alternatives with respect to all criteria are compared. In matrix (π), each alternative is compared with the other alternatives (table 13).

Table (13): Total preference matrix (π)

π	**A1**			**A2**			**A3**			**A4**			**A5**			**A6**		
A1	0.00	0.000	0.000	-0.359	0.361	0.975	-0.080	0.029	0.193	-0.070	0.110	0.269	-0.095	0.251	0.695	-0.027	0.311	0.736
A2	-0.016	0.070	0.218	0.000	0.000	0.000	0.000	0.000	0.000	-0.111	0.057	0.203	-0.094	0.080	0.238	-0.033	0.140	0.289
A3	0.158	0.638	1.272	0.033	0.901	1.782	0.000	0.000	0.000	0.041	0.504	1.100	-0.053	0.524	1.313	0.019	0.600	1.373
A4	-0.118	0.247	0.782	-0.118	0.486	1.314	-0.075	0.032	0.193	0.000	0.000	0.000	-0.157	0.151	0.624	-0.154	0.223	0.808
A5	0.072	0.337	0.671	-0.146	0.457	1.250	0.000	0.000	0.000	-0.106	0.099	0.417	0.000	0.000	0.000	-0.210	0.157	0.683
A6	0.072	0.320	0.644	-0.146	0.441	1.230	0.000	0.000	0.000	-0.029	0.095	0.271	-0.059	0.081	0.323	0.000	0.000	0.000
π-	0.168	1.612	3.587	-0.737	2.647	6.551	-0.156	0.060	0.386	-0.275	0.866	2.261	-0.457	1.087	3.193	-0.405	1.430	3.890

The $\tilde{\Phi}^{+}(\ )$ and $\tilde{\Phi}^{-}(\ )$outranking flow is calculated in table 14. Positive rating expresses how an alternative (a) affects other alternatives and ranks them. That would be the alternative power. As much as this number, the alternative is the better. Negative ratings indicate how an alternative is affected by other alternatives and is rated by them. This implies a weak alternative. This number is much lower, the better.

Table (14): Flow calculation for pre-ordering alternatives

$\sim^{+}(\ )$			$\sim^{-}(\ )$		
-0.631	1.062	2.868	0.168	1.612	3.587
-0.253	0.347	0.949	-0.737	2.647	6.551
0.198	3.166	6.840	-0.156	0.060	0.386
-0.622	1.139	3.721	-0.275	0.866	2.261
-0.391	1.051	3.021	-0.457	1.087	3.193
-0.162	0.938	2.469	-0.405	1.430	3.890

Table (15): The net flow

$\sim(\ )$		
-4.219	-0.550	2.701
-6.804	-2.300	1.686
-0.188	3.106	6.995
-2.883	0.273	3.996
-3.584	-0.037	3.478
-4.053	-0.492	2.874

Table (16): Defuzzification and Ranking of alternatives

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
A1	1.000	0.771	1.000	1.000	1.000	1.000
A2	1.000	1.000	1.000	1.000	1.000	1.000
A3	0.441	0.257	1.000	0.596	0.538	0.460
A4	0.872	0.640	1.000	1.000	0.954	0.883
A5	0.924	0.699	1.000	1.000	1.000	0.934
A6	0.991	0.760	1.000	1.000	1.000	1.000

V(Ci>C1,C2,C3,C4,C5,C6)	0.441	0.257	1.000	0.596	0.538	0.460
Weight	0.134	0.078	0.304	0.181	0.164	0.140
Rank	**5**	**6**	**1**	**2**	**3**	**4**

CONCLUTION

This paper has presented the integration of intuitionistic fuzzy preference relation and fuzzy PROMETHEE method for selecting the most desirable facility location. This work aimed to propose the use of a multi-criteria decision support for the prioritization location of static facilities. Selecting the wrong location for a new facility will increase the cost of decision makers and even in some cases it is irrecoverable. So any decision method which is less deviation would be more appropriate. The multi-criteria decision analysis is one of the evident areas of important points in integrated planning of the location problems. The model is presented based on the employment of four methodologies, F-Delphi, F-AHP, F-LLSM and F-PROMETHEE. This paper solves a factor rating system facility location allocation problem defined as follows:

In F-Delphi area

- Selection of location criteria for evaluating potential locations for hypermarket centers.
- The decision makers use their knowledge, prior experience with the hypermarket conditions of the city and the presence of sustainable freight regulations in the city to identify candidate locations for implementing hyper market center.

In F-AHP area

- Provide fuzzy total pairwise comparisons matrix of criteria.

In F-LLSM area

- Using F-LLSM and LINGO software to calculate weights of criteria.

In F-PROMETHEE area

- Provide: Fuzzy aggregated decision matrix; fuzzy Preference matrix for all criteria; total

  Preference matrix ( ); flow calculation for pre-ordering alternatives and the net flow.

Finally defuzzification and Ranking of alternatives must be done. According to Table 16, prioritization of proposed location is calculated as follows: ***location3 > location4 > location5 > location6 > location1 > location2.***

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