VOLUME 2 NUMBER 1 May 2013

ISSN 2304-7712 (Print)
ISSN 2304-7720 (Online)

International Journal of Advanced Engineering and Science

ELITE HALL PUBLISHING HOUSE

International Journal of Advanced Engineering and Science

ABOUT JOURNAL

The International Journal of Advanced Engineering and Science (Int. j. adv. eng. sci. / IJAES) was first published in 2012, and is published semi-annually (May and November). IJAES is indexed and abstracted in: ProQuest, Electronic Journals Library, getCITED, ResearchBib, IndexCopernicus, Open J-Gate and JournalSeek. Since 2013, the IJAES has been included into the ProQuest one of the leading full-text databases around the world.

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ISSN 2304-7712

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International Journal of Advanced Engineering and Science

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ISSN 2304-7712

International Journal of Advanced Engineering and Science

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ISSN 2304-7712 (Print)
ISSN 2304-7720 (Online)

The Integration of Fuzzy Multi Criteria Decision Making Methods for Product Ranking

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Abstract

Decision Making (DM) always is one of the main purposes of Operation Research (OR).Related to the importance of quantitative and qualitative factor's we have to use method's that include them both, one of these techniques is Fuzzy logic. Many of commercial companies do not use scientific methods for ordering goods, and usually orders are made by personal opinion. Such decision making will increase organizational costs and reduce their profit.

In this Article we are going to review methods that can help commercial organization's to predict and order good's, that will reduce companies costs and increase their incomes. To reach this target we have to use qualitative and quantitative element's that effect companies profit beside each other. For including both factors we have to use Multiple Criteria Decision Making (MCDM) method's .With this technique we can reach to all planned target's by considering qualitative and quantitative elements. The second issue we have to consider is the growth of uncertainty, the method that can include uncertainty in decision making is fuzzy logic. We will combine MCDM with fuzzy sets to make profitable suggestions for commercial companies. To reach this target we have used a Commercial Company as a case of study and used this company manager's as consultants.

As a review in this thesis, first alternatives and qualitative criteria's will be identified by consultant's opinions, by the use of Delphi Technique. Then, decision making matrix will be completed and criteria's weight will be calculated by the average of consultant's opinion, with the use of Likert Questionnaire. Finally, three fuzzy methods, De-fuzzy- Fuzzy TOPSIS and FDM software will sort the alternatives.

Key Words: Multiple criteria decision making (MCDM), Alternative's Ranking, Delphi Method, Fuzzy sets.

Introduction

The speedy and increasingly daily changes make our setting changeable. In these unstable circumstances

Repeat programming or strategy-making confront life firms to dangerous. The essential of improvement on such settings is flexibility.

One of the successful criteria on the importing and exporting is influential investment on the goods purchase. The commercial firms must select those good purchase strategies that maximize their sales and profits and minimize their costs. The forecasting sales methods can be useful but their efficiencies are limited. Because the managers can not invest base on next sales and must look at other criteria. Besides some of required criteria for managers, are not quantifiable. These criteria are depended on the mental judgments. The Aristotle binary logic does not have post value and instead of it Fuzzy logic was substituted. Therefore is used Fuzzy logic for transformation judgmental language. Variety of the decision-making variables leads to there is not comprehensive source for variable specification. Therefore the most effective source is expert's views.

The aim of this research based on above matters is introduce a procedure for importer and exporter firms specify and evaluation of the influential factors on the purchase and good ranking based on customer utility. Based on the empirical founding about one commercial firm we ranked choices of action .On the first we gathered experts views about selection choices, criteria determination and weight allocation to each choice. On the next sections we will explain details of founding and research methodology after literature review.

Literature Review

In our research we used integration of the multi-variables decision- making, Delphi, Fuzzy logic and integration method for goal achieving. Fuzzy Set Theory (FST), as pioneered by Lotfizadeh, allows for vague boundaries and provides a mechanism to utilize fuzziness or imprecise information of preferences, constraints, and goals. [5] In decision making. Fuzzy logic enables the decision-maker to emulate the human reasoning process with vague or imprecise data. [3]

With considering TOPSIS method as the main tool in this research, and related to the final aim of our paper, many researchers have been working on combining multi criteria decision making methods for ranking, sorting and selecting suppliers, goods, manufacturers, retailers and est. In 2008 integrating TOPSIS with multi objective decision making was used for supplier selection.[13]. A complete model also was designed in the same year. [15] A year later fuzzy TOPSIS method was used during the information technology outsourcing selection. [4] Group MCDM was also used in 2005 for selection and sorting problems. [26]In addition and by increasing the role of supply chains in every economy and industry, a MCDM revised model was proposed. [27]

Combining two different kinds of MCDM methods is also used by many researchers. In 2009 a mixed fuzzy TOPSIS with Entropy was used for selection problems. [12] Previously in 2007 a fuzzy AHP and TOPSIS method was used for project selection. [16]

Delphi method

The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts.[10] In the standard version, the experts answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. It is believed that during this process the range of the answers will decrease and the group will converge towards the "correct" answer. Finally, the process is stopped after a pre-defined stop criterion (e.g. number of rounds, achievement of consensus, and stability of results) and the mean or median scores of the final rounds determine the results.[24]

Other versions, such as the Policy Delphi, [21] have been designed for normative and explorative use, particularly in the area of social policy and public health.[18] In Europe, more recent web-based experiments have used the Delphi method as a communication technique for interactive decision-making and e-democracy.[17]

Delphi is based on the principle that forecasts (or decisions) from a structured group of individuals are more accurate than those from unstructured groups.[25] This has been indicated with the term "collective intelligence".[11] The technique can also be adapted for use in face-to-face meetings, and is then called mini-Delphi or Estimate-Talk-Estimate (ETE). Delphi has been widely used for business forecasting and has certain advantages over another structured forecasting approach, prediction markets. [8]

Delphi method was introduced with Round Research Company in USA for 1959 year .The objective of this method is to participate many of people for decision making. Delphi method is the process of organizing writhed communication between problems solving big group. This group is arranged proportion with type problem, and objectives of problem solving. [28]

This method based on this principle that; the best problem-solving way for which do not have a subjective and precise answer is interviewing from experts. The purpose of Delphi method practices is reliable and innovative viewing for decision-making information production. [9] Muller at el. (1994) said that Delphi method stages include:

Problem definition, decision-maker selection based on required skills, questionnaire design sending, receiving and analyzing completed questionnaires, views integration, responses classification and repeating this process until experts' agreements are performed.[19]

Multi criteria Decision-making

Herbert Symons says that decision-making is basis for all managers' activities. Decision-making for each level of organizational level can be performed with several thinking methods. But this process often needs precise and step-wise method. Decision-making methods are divided to many categories. One of these categories divides techniques of decision-making to two class; one-criterion and multi criteria. In general every decision-making problem has one or several criteria such as; profit, cost, time, satisfaction, distance, utility…

If aim of decision is one of these criteria, it shall define one-criterion problem. But those problems that have more than one criterion are named multi-criteria problems.

On the recent decades multi-criteria models were used increasingly. There were used for problem-solving such as; organizational, general, governmental, military, and transportation… problems.

Based on the general definition, multi-criteria decision-making are problems such as; especial or preference problems, evaluation, multi choices selections.

There are several multi-criteria methods. These methods based on processing data procedure are divided to; compensations and un-compensations methods. Un-compensations methods are those procedures that transaction between criteria is not allowable. In these methods, each criterion is in-dependant and evaluation is performed for each criterion independently. The compensations methods are those procedures that transaction between their criteria is authorized. These methods are categorized to three groups as follows:

1. Point's methods; these methods estimate a utility function for each choice and the best choice is selected base on the maximum utilities.
2. Aggregation methods; that based on which the best choice is based on minimum gap between choice and ideal choice.
3. Homogenous methods; the results of these methods are set of ranks that prepares required comparison. [1]

Fuzzy Methods

Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. [23] Furthermore, when linguistic variables are used, these degrees may be managed by specific functions.

Fuzzy logic began with the 1965 proposal of fuzzy set theory by Lotfizadeh.[7][30] Fuzzy logic has been applied to many fields, from control theory to artificial intelligence. The most of managerial decision –making procedures and techniques are deterministic. These methods have limited usage because the circumstances are not predictable yet.

Manblack and Asgarzadeh introduced Fuzzy method. On the deterministic sets each number or element is or is not belonged to a certain set. For example suppose X={1,2,3,4,5} and A={2,3,4} as a subset of X . Membership for 1 and 5 is zero and for 2, 3, 4 is one. But on the Fuzzy sets, membership is defined zero to one instead of zero or one. Fuzzy number sets are used increasingly. We used triangular Fuzzy numbers based on the experts interviewing. A triangular Fuzzy number is defined as three elements such as A= {a1, a2, a3} that is drawled as exhibit (1)

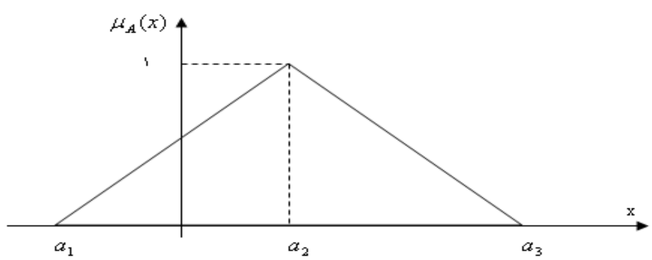


Exhibit 1: Triangular Fuzzy Number

Based on the exhibit (1) membership function is defined as follows:

$$\mu_A(x) = \begin{cases} 0 & x < a_1 \\ \dfrac{x - a_1}{a_2 - a_1} & a_1 \le x \le a_2 \\ \dfrac{a_2 - x}{a_3 - a_2} & a_2 \le x \le a_3 \\ 0 & x > a_3 \end{cases}$$

All of the mathematical calculations are allowed for Fuzzy numbers

Integration Rank Methods

There are several models such as Total Weighted, TOPSIS, AHP... for criteria ranking. Sometimes decision-makers do not limit their ranking methods. They select several methods that they have difference results. Integration methods are used for integration of different methods results. These methods are includes winning and Copland. [20] We used three different methods for criteria ranking. Then the ranking results were integrated. Next the average of each goods-group ranks was determined as final group rank.

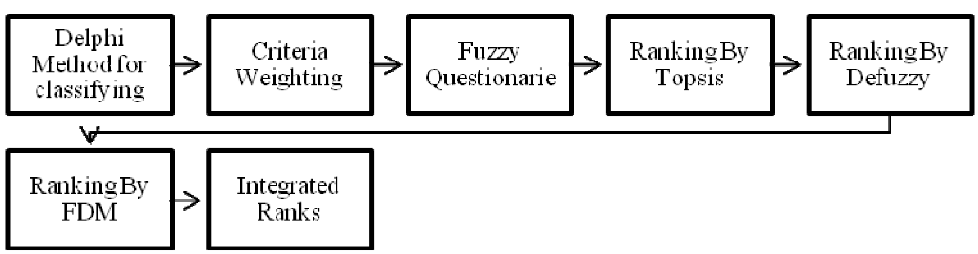
Research Design

Sampling

Our statistical community was all of exports and specialists that had determinant view on one of the Iranian big commercial firm. We selected all of them without random sampling.

Research Methodology

The main problems on our commercial firm were; 1) imports or exports goods grouping, 2) ranking in the first we specified firm experts. Then we used Delphi method for goods groping and ranking based on the firm experts views. Then we determined comparison criteria for goods ranking. These criteria to deterministic (quantify) and expert's views (objective) that attained with Delphi method. After determination goods and criteria, was made decision – making matrix. Then relatively situation of each choice based of each criterion was determined. The methodology used in this research is mentioned as diagram below:



The export views or judgmental variable were explained with Likert scale. Then judgmental or quality variables were converted to triangular fuzzy numbers based on fuzzy logic. Next by fuzzy numbers processing, we compared choices and determined rank and priority of choices.

We divided 390 items of goods on especial groups for choices definition. The goods firm can divide to goods groups. This grouping simplified and averaged our decision – making problem and foliated suitable decision – making. Furthermore we executed Delphi method. The first we specified 6 persons of firms managers as export peoples. Then we asked experts that they group firm goods. We participated with experts for goods ranking, on the end we determined four groups of goods included; medical requirements, house requirements, chi ken requirements and luxury requirements.

After choices definition we specified choices comparison criteria. Then we divided these criteria on two groups (quantity, quality, objective or subjective). The quantity variables were included profit of each goods group (C1), waste time for goods purchase (C2), were gathered from accounting and other documents. Quality data were gathered by Delphi method. For this purpose we repaid a questionnaire and distributed it between firm's experts. After four it ration following criteria were specified:

Table 1: Quality criteria for groups ranking

Criteria	Type	Code
Customer satisfaction	Positive	D1
Goods Quality	Positive	D2
Reliability	Positive	D3
Simplify of transport	Positive	D4
Competition	Negative	D5
Next fortunate	Positive	D6

Then we prepared a questioner and distributed it between firm's experts for determination weight of each criteria. The importance of each criteria was determined by expert's views. Then was computed average of experts, views. For this reason quality data were converted to triangular fuzzy data as we showed on table (2), [22]

Table 2: fuzzy conversion

Quality criteria	Triangular fuzzy criteria
Very , very much	(9,9,10)
very much	(7,9,9)
Much	(3,5,7)
Little	(1,3,5)
Very little	(0,1,3)
Very, very, little	(0,1,1)

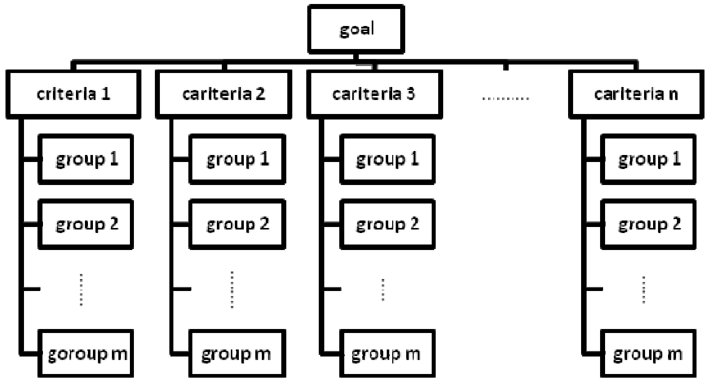
The average weighs of experts views was showed on table (3)

Table 3: Experts views average

Weight	Criterion
(6/3,7/6,9)	Customer satisfaction
(6, 7/6,8/8)	Goods Quality
(4/6,6/8,6/3)	Reliability
(2/5,4,1/3)	Simplify of transport
(2/1,3,6/5)	Competition
(4/3,4/6,8)	Next fortunate
(0/87,0/9,0/98)	Goods group profit
(0/6,2,3/3)	Wasted time

As we showed on exhibit 2 decision-making matrix has four choices and eight criteria. Our criteria include two quantity and six quality criteria as followed on exhibit (2).

Exhibit 2: hire chi of decision making



Then we must define our decision-making matrix for choices ranking. The table 4 was showed this matrix. For this table was arranged a meeting of experts for three hours.

Table 4: decision-making matrix

Weights	Criteria	Medical	Furniture	Metal(steel)	Luxury
(6.3 ,7.6 ,9)	Customer satisfaction	(8,9,9.5)	(5.3,7.3,8.6)	(7,8.3,9.3)	(5,7,8.6)
(6.7 ,6 ,8.8)	Quality	(8.3,9,9.6)	(4.6,6.3,8.1)	(6,8,9)	(5,7,8)
(4.6 ,6.8 ,6.3)	Reliability	(8,9,9.5)	(3,5,7)	(4.3,6.3,7.6)	(4,6,7.6)
(2.4 ,1,5.3)	Transportation	(3.3,5.3,7.3)	(1.3,3.3,5.3)	(5.3,7.3,9)	(5.6,7.6,9.3)
(2.1 ,3 ,6.5)	Competition	(0.6,2.3,3.6)	(6.3,8,8.8)	(1.5,3.3,6.3)	(1,2.6,4.3)
(4.3,4.6,8)	Improvement	(1.5,3.3,5.3)	(4.6,6.8,6.3)	(4.3,6.3,8)	(3.6,5.6,7.6)
(0.87,0.9,0.98)	Profit	226038500	81310570	38396610	84579450
(0.6,2,3.3)	Wait time	31.2	6.8	1.3	2.8

We used 2 equations for elimination the scale of decision-making matrix, these equations are as following: [14]

1. Profit = maximization criteria Rij / MaxRij
2. Cost = minimization criteria MinRij / Rij

On the other words for profit criteria we divided by each element to maximum of their criteria elements to each related element for this reasons was used maximum or minimum three angular fuzzy numbers. On the second stage we made weighted matrix. For this matrix we multiplied weight or importance of each criterion by weights or importance's coefficients of each choice. If Nij is without scale decision-making matrix and Wij is weighted matrix of criteria, Vij or find weighted matrix will be computed from multiple of NJ. [29]

$$V_{ij} = W_{ij} \otimes N_{ij}$$

The find weighted matrix was shown on table 5.

Table 5: Find weighted matrix

Code	D1	D2	D3	D4
A1	(0.52,0.71,0.9)	(0.5,0.69,0.85)	(0.38,0.61,0.81)	(0.07,0.22,0.4)
A2	(0.34,0.57,0.81)	(0.27,0.5,0.73)	(0.14,0.34,0.59)	(0.02,0.13,0.29)
A3	(0.45,0.66,0.87)	(0.36,0.61,0.82)	(0.2,0.42,0.65)	(0.11,0.03,0.49)
A4	(0.32,0.55,0.81)	(0.3,0.55,0.71)	(0.18,0.4,0.65)	(0.12,0.32,0.51)
Code	**D5**	**D6**	**C1**	**C2**
A1	(0.02,0.07,0.4)	(0.07,0.13,0.5)	(0.87,0.9,0.98)	(0.001,0.006,0.01)

A2	(0.011,0.021,0.03)	(0.23,0.36,0.8)	(0.31,0.32,0.35)	(0.008,0.03,0.05)
A3	(0.014,0.06,0.16)	(0.21,0.34,0.76)	(0.14,0.15,0.16)	(0.06,02,0.33)
A4	(0.02,0.06,0.25)	(0.18,0.31,0.72)	(0.32,0.33,0.36)	(0.02,0.07,0.1)

Founding's:

At present we can compute ranking of choices. Base on previous concepts we ranked goods groups which; fuzzy TOPSIS, de – fuzzy and fuzzy package. We used integrated all results of three methods.

De-fuzzy ranking

Base on this method we computed total point of each choice as a triangular fuzzy number and then converted it to deterministic number for choices, ranking. Therefore on the first we computed total point of each choice by adding all of row elements normal weighted points. Then we used following equation for conversion fuzzy points to determine stick points:

$$G_M = \frac{a + 4b + c}{6}$$

This equation was used for all of choices and computed rank of each choice as table 6.

Table 6: Goods ranking with De-fuzzy method

Row	Group	Code	Total of fuzzy point	Total of determines tic points	Rank
1	Medical	A1	(2.43,3.33,4.85)	3.433	1
2	Furniture	A2	(1.32,2.27,3.65)	2.3416	4
3	Metal(steel)	A3	(1.54,2.74,4.24)	2.79	2
4	Luxury	A4	(1.46,2.59,4.11)	2.655	3

TOPSIS ranking

Based on fuzzy TOPSIS are determined ideal fuzzy negative or positive choices. The ideal fuzzy positive choice is noted by A~j. There are three methods for these vectors computation:

1. Chen & lean method (2005): base on this method, maximum of three – angular fuzzy number is selected for A~j+. Computation. Then minimum of three – angular fuzzy number is selected for A~j. computation .[6]

$$FPIS = A^{+} = (V_1^{+}, V_2^{+}, ..., \tilde{V}_n^{+}) \xrightarrow{Where} \tilde{V}_j^{+} = Max\{V_{ij3}\}$$

$$FNIS = A^{-} = (V_1^{-}, V_2^{-}, ..., \tilde{V}_n^{-}) \xrightarrow{Where} \tilde{V}_j^{-} = Min\{V_{ij1}\}$$

2. Wang method (2007) : based this method ideal positive choice equals (1,1,1) and ideal negative choice equals (0,0,0) .[29]
3. Jahanshaholoo & Izadkhah method (2006): Based on this method ideal positive choice equals maximum of three – angular fuzzy numbers. In this method ideal negative choice equals minimum of three – angular fuzzy numbers .[14]

$$FPIS = A^{+} = (Max\{V_{ij1}\}, Max\{V_{ij2}\}, Max\{V_{ij3}\})$$

$$FNIS = A^{-} = (Min\{V_{ij1}\}, Min\{V_{ij2}\}, Min\{V_{ij3}\})$$

In this article we used Chen – lean method. Negative and positive ideal vectors were showed on table 7.

Table 7: fuzzy Ideal

Criteria	D1	D2	D3	D4	D5	D6	C1	C2
Positive ideal	0.9	0.88	0.83	0.53	0.5	0.8	0.98	0.33
Negative ideal	0.32	0.21	0.09	0.002	0.011	0.07	0.008	0.001

On the next step difference between positive and negative ideals way computed. The different between each choice from positive ideal choice was defined with di+ .and the difference between each di- . For this reason 2 equations used as fallows [6]:

$$d_i^+ = \sum_{j=1}^{n} d_v(V_{ij}, V_j^+), d_i^- = \sum_{j=1}^{n} d_v(V_{ij}, V_j^-) \quad i = 1,2,\ldots,m$$

The dv (vij, v~j-) on above equations is explained difference between choice s situation from fuzzy ideal choice. It is computed as follows:

$$d_v(\tilde{m}, \tilde{n}) = \sqrt{\frac{(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2}{3}}$$

$$\tilde{m} = (m_1, m_2, m_3),\ \tilde{n} = (n_1, n_2, n_3)$$

The of each choice s differences from positive and negative ideal was defined as di- , di+. After these computations, closeness coefficient or CCI index is calculated for each choice. For this reason following equation is used. [29]

$$CC = \frac{d_i^-}{d_i^- + d_i^+} \xrightarrow{Where} i = 1,2,\ldots,m$$

On the next step, all choices are descending arranged (from maximum to minimum). We showed differences of each ideal vector and theirs closeness coefficients on table 8.

Table 8: fuzzy – top sis group ranking

Group	d_i+	d_i-	cc_i	Rank
A1	2.5	3.11	0.55	1
A2	3.51	2.1	0.37	4
A3	3.22	2.42	0.42	2
A4	3.247	2.33	0.41	3

Group Ranking with FDM fuzzy package there are several Fuzzy packages such as ; fuzzy decision making (FDM), fuzzy gen(FG) , fuzzy tech(FT), ... We used FDM package in this article. In this package with definition of choices, criteria, criteria type (objective or subjective, fuzzy or deterministic) and importance degree of each criteria, we make decision – making matrix. Then with completion each cell of matrix and run exciting calculated ranks of choices. There is showed package ranking result on exhibit (3).

Exhibit 3: package ranking choices

Group	Code	Points	Rank
Medical	A1	94.96	1
Furniture	A2	78.54	2
Metal(steel)	A3	70.53	3
Luxury	A4	47.73	4

Result Integration

After goods ranking with each fuzzy method we can integrate results of three methods , we calculation . Integration results are showed on table (9):

Table 9: Integration ranking results

Grope	Code	Top sis ranking	De-fuzzy ranking	Package ranking	Average
Medical	A1	1	1	1	1
Furniture	A2	4	4	4	4
Metal(steel)	A3	2	2	2	2
Luxury	A4	3	3	3	3

As showed on table 9 ranking results of three fuzzy methods are seemly. For this reason if we used cap land or winning methods for integration, result will be not changed.

Conclusion

This article is based on empirical research related with a active Iranian commercial firm. This firm purchases (imports) and sells (exports) 390 goods types. The decision making process in this firm do not follow from any especial principal and increase firms costs. Un-sailed and loosed sales are affected cists increasing. All of firms goods purchase based on firm boss and sales manager views. They do not use any subjective of objective criteria.

This research was performed based on objective and subjective criteria. In the first step we specified all of quantities and views. On the second step we converted qualities (objective) experts views to quantities (subjective) numbers based on fuzzy logic and triangular fuzzy numbers. On the second step were ranked firms goods groups with each fuzzy method. We divided all of firm s goods to four group based on Delphi and step – wise expert view surveying.

On the find step were integrated results of fuzzy multi – methods. For this purpose, we calculated average of three methods results. As an interesting point we observed that results of three fuzzy methods were same, therefore average of ranks was same as results of each method. We proposed for next researches that combine linear or goal programming whit fuzzy methods. Or they can rank integration of Delphi and fuzzy methods. We used three – angular fuzzy number and they can utilize other fuzzy numbers.

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