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Estimation of Potential Locations of Trade Objects on the Basis of Fuzzy Set Theory

Ramiz Balashirin Oglu Alekperov and
Vuqar Mamedali Oglu Salahli

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ESTİMATİON OF POTENTİAL LOCATİONS OF TRADE OBJECTS ON THE BASİS OF FUZZY SET THEORY

Alekperov Ramiz Balashirin oglu[1],

PhD, Associate Professor, Head Engineer
Azerimed LLC Baku, Azerbaijan
ramizalekper@gmail.com

Salahli Vuqar Mamadali oglu[2]

Odlar Yurdu University, Baku, Azerbaijan
vsalahli@ekin.com

Abstract. In the present article, we have considered the issue of selection of potential locations of trade objects as a multi-factor decision-making in the conditions of uncertainty by applying the theory of fuzzy sets. Examples were given to assess the location options of commercial enterprises and the potential location options of the facilities on these samples were assessed on the basis of a fuzzy extraction method in the notation MATLAB \ Fuzzy Inferences Systems.

Keywords: Commercial establishments, multi-criteria decision-making, fuzzy sets, fuzzy logic derivation, multi-factor decision-making

1. Introduction

The main purpose of commercial enterprises is to provide goods or services to customers in order to meet consumer needs. Thus [1,2,3,4]:

- Due to the large number of sales, end customer needs are met at the place of residence or workplace. At the same time, large volumes of products from the supplier are broken down into smaller parts that meet the wishes and needs of the last customer;
- Through trade, the producer receives information about the demand for goods, which is the most sensitive indicator in the regulation of production;
- New markets are being developed and new products are being promoted through trade;
- The commercial activity performs the advertising functions of the producers' products.

The most common and major mistake when choosing a method of selecting and evaluating the location of new branches and outlets in commercial enterprises is to evaluate only one location. The essence of this parable is to identify and select the best object with maximum potential from several different proposals.

Most retailers in our country build their successful trading network on an intuitive approach. This method is justified as long as it allows the owners of the firm to participate directly in the selection of the scope of work and facilities. However, the

economic situation requires that the existing methods be used to reduce the risks when deciding to open new facilities.

Choosing which approach or method to use is not a simple matter for every retailer. Research and experience on such projects show that the response depends on a good understanding of management requirements, the reasons for the successes and failures of past experiences, the data obtained from business analysis and the methods used to assess site-facility efficiency.

2. Methods of selecting the potential location of the trade object

Modern methods of solving this problem [3,4]: 1. financial analysis; 2. checklists 3. analogical comparison approach 4. use of the Huff gravitation model 5. regression analysis methods.

In the research work, these methods were analyzed in detail and their main features were investigated:

1. The method of financial analysis - consists of the evaluation of the proposed object on the basis of current rental prices and the selection of an expert on the basis of these indicators. In one way or another, the rental price is taken into account when deciding for each location.
2. Checklists - Most are used to pre-select potential areas for retailing. Based on the set of parameters, there are a number of procedures adopted to assess the location of any object: the area of an object, the convenience of access roads, the proximity of competitors, the presence of shop windows and billboards, etc. In fact, these are mandatory place requirements that can be seen in retail outlets or in advertisements looking for "rental housing". Sometimes, in order to decide on the selection of the most successful locations, the company's experts measure and evaluate each parameter and then rank the objects according to the accumulated points.
3. Analog comparison method - is to calculate the possible sales volume for a new object (by comparison) according to the object of the same distribution network with a similar feature.
4. The method of using the Huff gravitational model. Based on the assumption that the buyer chooses a store to shop in two ways: the area of the store (the larger the better) and the distance to the exit (the smaller the better). Moreover, the dependence on these parameters repeats Newton's law of gravitation. By knowing the speed of consumption of products, the number of residents and the availability of the facility, the geography of the population in the area, the location and coordinates of the main competitors, you can calculate the potential of the site in terms of future traffic. This is a classic geomarketing tool.
5. Regression analysis method. This allows you to estimate the location of any selected parameter, for example, in relation to other parameters of trade turnover. This method is more statistical and accurate than checklists and analog comparison methods. To implement this method, it is necessary to identify, measure and analyze the factors that affect the efficiency of the store and determine the degree of impact on the final or intermediate indicator. The

simplest example of such a dependency is the assessment of the conversion rate of visitors into buyers. Everyone understands that there is a connection here, but after research, only a few retailers can turn this dependence into a formula. It often turns out that this connection is not simple, and without learning it, a big mistake can be made in calculating the sales potential of the future store.

3. Problem statement

As a result of the analysis of the above methods and research, socio-economic factors influencing the selection of new branches and outlets in commercial enterprises [4] have been identified and grouped (Table 1).

The analysis revealed that:

1. The success of a business is determined by its location in the most crowded places. These are, first of all, the city center, urban centers, main transport routes, subway zones, central avenues and streets. However, the purchase price of a lease or facility is also a very important factor for an enterprise.
2. Surveys conducted among the population revealed that the following factors influenced the choice of the place of shopping [6]: price - 38%, quality - 38%, range - 42%, staff - 27%, ease of accommodation - 35%, service - 10%, services - 27%, purchase incentives - 5%, advertising - 15%, atmosphere - 18%, reputation - 20%.

Basically, several possible options for the placement of commercial facilities are mentioned, and one of the alternatives is preferred by making an objective comparison between them.

The analysis of the above-mentioned methods for solving the problem of choosing the potential location of the trade object and the factors influencing this selection process allow us to argue that this issue is a matter of choosing alternatives in a multi-criteria environment and implemented under various socio-economic factors.

Table 1. Criteria for evaluating the location options of commercial enterprises

Buyers (potential, real)	Obstacles	Competition	Expenses
• Quantity • Income level • Cost structure • Population density • Life style • Private vehicles	• Appearance • Flood of people • Obstacles (d/y, major highways) • Location type • Transport exchange • Condition of roads • Parking • Public transport	• Level of competition • Types of competing firms • Saturation index • Proximity of competitors (market leaders, Large firms)	• Construction costs • Rent • Salary level • Taxes • Transportation costs

The analysis of the available methods once again shows that the criteria that affect the implementation of the task are the most subjective, uncertain, difficult to formalize.

Recent problems are solved on the basis of the application of the theory of non-volatile sets [5], which allows to take into account the knowledge and experience of specialists and to take into account the uncertainty and difficult formalized factors.

In this regard, we have proposed to consider the issue of selection of potential locations of trade objects as a matter of decision-making in the conditions of uncertainty by applying the theory of fuzzy sets [6].

4. The method of solving the problem of multi-criteria decision-making on the location of commercial facilities on the basis of the application of fuzzy set theory

Trading associations usually help to develop a rating system that helps to choose the geographical location of a particular object. In the example, Table 1 proposes a system of 10 employee assessments that allows to assess any prospective geographical location of the enterprise for the repair of household appliances [4].

As shown in Table 2, all alternatives scored the same number of points. From this point of view, in such cases, it is necessary to give preference to the knowledge and experience of managers and make a choice taking into account the weight of the criteria. As noted, the best way to solve this type of problem is fuzzy logic methods [5,6]. From this point of view, the task we performed for the case was considered as a point-by-point evaluation of alternatives under conditions of uncertainty.

Thus, as in [4], suppose that the managers identified the possible placement options of the objects as in Table 2 and evaluated them on different scores on 8 criteria.

As can be seen from Table 2, the alternative placement options for the object are marked as A- a1, B - a2 and C- a3, respectively. The normal concept here is the N column in Table 2 - the intervals defined by managers for each criterion.

It is proposed to conduct a numerical (point) evaluation of alternatives on the basis of the following judgments, which do not constitute the following contradictions and are formed by managers:

R1: If K1 = “High flow of people passing by the facility” and K2 = “Relative purchasing power per inhabitant is low” and K3 = “If the number of customers in the area of influence is small” and K4 = “The sales area of the facility is very large” and K5 = “Sales If the area allows a full view ” K6 = "If the number of stops around the object is small" and K7 = "If home delivery is high" and K8 = "If public transport is 3 minutes away" Then Q = "It is enough to place the object in these coordinates" ;

R2: If K1 = “High flow of people passing by the facility” and K2 = “Relative purchasing power per inhabitant is high” and K3 = “If there is a large number of customers in the area of influence” and K4 = “If the sales area of the facility is very large” and K5 = “Sales If the area allows less full view ” and If the area allows less full view ” and K6 = “If the number of stops around the object is high” and K7 = “If home delivery is high” and K8 = “If public transport is 3 minutes away” Then Q = “It is very expedient to place the object in these coordinates” ;

R3: If K1 = "High flow of people passing by the object" and K2 = "Relative purchasing power per inhabitant is high" and K3 = "If the number of customers in the area of influence is high" and K4 = "If the object has a large sales area" and K5 = "Sales If the area allows a full view ”and K6 =“ If there are many stops around the object ”and

K7 =“ If home delivery is high ”and K8 =“ If public transport is 3 minutes away ”then Q =“ It is more expedient to place the object in these coordinates ”;

Table 2. Examples for assessing the location options of commercial enterprises

№	Criteria (K)	Evaluation (Q – satisfactory)				
		Norms (N)	Cretier's weight (w)	Alternative options (V)		
				$A(a_1)$	$B(a_2)$	$C(a_3)$
K_2	Relative purchasing power for a resident	for a residen t 200	2	100	66.67	75
K_3	Number of customers in the impact zone	8000	3	66.67	79.17	95.83
K_1	The flow of passers-by within 1 hour	500	1	62.33	83.33	50
K_4	The width of the sales area of the object	min 800 kv.m	4	79.17	83.33	91.67
K_5	Area of sales outlets	min 40 kv.m.	5	100	100	83.33
K_6	Number of stops	min 10 places	5	75	91.67	100
K_7	Possibility of delivery	-	6	96	83.33	90
K_8	Public transport	3 minute s away	7	100	91.67	93.34
	Sums for comparison			679.17	679.17	679.17

R4: If K1 = “High flow of people passing by the object” and K2 = “Relative purchasing power per inhabitant is high” and K3 = “If there is a large number of customers in the area of influence” and K4 = “If the object has a small sales area” and K5 = “Sales If the area allows less full view ”and K6 =“ If the number of stops around the object is small ”and K7 =“ If home delivery is low ”and K8 =“ If public transport is less than 3 minutes” then Q =“ It is expedient to place the object in these coordinates ”;

R5: If K1 = "Low flow of people passing by the object" and K2 = "Relative purchasing power per inhabitant is low" and K3 = "If the number of customers in the area of influence is small" Then Q = "It is not expedient to place the object in these coordinates";

R6: If K1 = "Low flow of people passing by the facility" and K2 = "Relative purchasing power per inhabitant is average" and K3 = "If the number of customers in the area of influence is average" and K4 = "If the sales area of the facility is average" and K6 = " If the number of stops around is middle " and K8 =" If public transport is average than 3 minutes "Then Q =" It is enough to place the object in these coordinates ";

Restoring the classification (application of fuzzy) of the terms in the left part of the rules considered on the basis of the criteria $\mu(u) = \exp\left(-(u-10)^2 / \sigma_k^2\right)$ (k=1÷8) K1, K2, K3, K4, K5, K6, K7, K8 on the reference vector of fuzzy sets (a1, a2, a3) (k = 1¸ 8) with the help of the Gaussian membership function [5,6] (Figure 1) (where the values for σ_k are selected depending on the degree of significance of the criteria K1, K2, K3, K4, K5, K6, K7, K8, for our case σ = 20 + w).

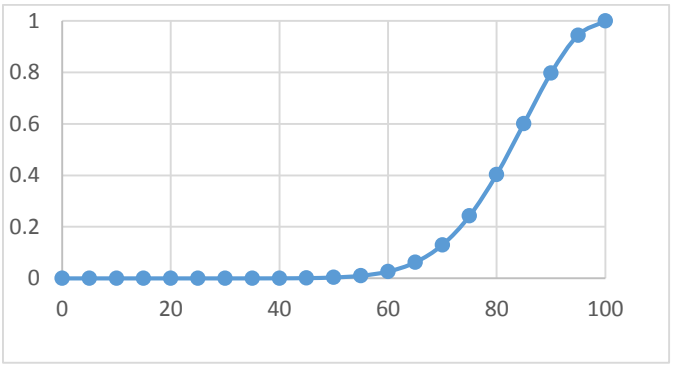

Fig. 1. Gauss membership function

For each criterion, three term sets were used, taking into account their weight ratios (Table 2): Low, Middle, High. Figure 2 shows a graphical representation of the term-sets corresponding to the criterion of human flow K1 - passing through the object. According to Table 1, the calculated values for the high-term set of the Gaussian membership function for each alternative and criterion are given:

HUMAN FLOW THROUGH THE OBJECT FOR 1 HOUR:

$$\tilde{K_1} = \frac{0.0400}{a_1} + \frac{0.5325}{a_2} + \frac{0.0035}{a_3};$$

NUMBER OF CUSTOMERS IN THE EFFECT ZONE:

$$\tilde{K_2} = \frac{1}{a_1} + \frac{0.1007}{a_2} + \frac{0.2749}{a_3};$$

RELATED BUYING POSSIBILITY FOR A RESIDENT:

$$\tilde{K}_3 = \frac{0.1225}{a_1} + \frac{0.4403}{a_2} + \frac{0.9677}{a_3};$$

WIDE RANGE OF SALE OF THE OBJECT:

$$\tilde{K}_4 = \frac{0.4703}{a_1} + \frac{0.6173}{a_2} + \frac{0.8865}{a_3};$$

AREA OF SHOPPING SALES:

$$\tilde{K}_5 = \frac{1}{a_1} + \frac{1}{a_2} + \frac{0.6411}{a_3};$$

NUMBER OF STATIONS:

$$\tilde{K}_6 = \frac{0.3679}{a_1} + \frac{0.8949}{a_2} + \frac{1}{a_3};$$

DELIVERY OPPORTUNITY:

$$\tilde{K}_7 = \frac{0.9766}{a_1} + \frac{0.6629}{a_2} + \frac{0.8625}{a_3};$$

PUBLIC TRANSPORT :

$$\tilde{K}_8 = \frac{1}{a_1} + \frac{0.9092}{a_2} + \frac{0.9410}{a_3};$$

Expediency of choosing alternatives - term-sets used to describe the linguistic variable *Y* and their *P* = {0; 0.1; 0.2; ...; 1} the following have been selected as membership functions that characterize a discrete set: E - PURPOSEFUL, ME - MORE PURPOSEFUL, SE - ENOUGH (PURPOSEFUL), VE - VERY PURPOSEFUL, UE - NOT PURPOSEFUL. Figure 3 shows a graphical representation of the term sets used to describe the linguistic variable *Y*.

Given these formalisms, let us express the fuzzy rules outlined above as follows:

R_1: IF $X_1 = K_1$ is high and $X_2 = K_2$ is low and $X_3 = K_3$ is low and $X_4 = K_4$ is high and $X_5 = K_5$ is high and $X_6 = K_6$ is low and $X_7 = K_7$ is high and $X_8 = K_8$ is high then $Y = SE$;

R_2: IF $X_1 = K_1$ is high and $X_2 = K_2$ is high and $X_3 = K_3$ is high and $X_4 = K_4$ is high and $X_5 = K_5$ is low and $X_6 = K_6$ is high and $X_7 = K_7$ is high and $X_8 = K_8$ is high then $Y = VE$;

R_3: IF $X_1 = K_1$ is high and $X_2 = K_2$ is high and $X_3 = K_3$ is high and $X_4 = K_4$ is high

and X_5= K_5 is high and X_6= K_6 is high and X_7= K_7 is high and X_8= K_8 is high then Y= ME ;

R_4: IF X_1= K_1 is high and X_2= K_2 is high and X_3= K_3 is high and X_4= K_4 is low and X_5= K_5 is low and X_6= K_6 is low and X_7= K_7 is low and X_8= K_8 is low then Y= E ;

R_5: IF X_1= K_1 is low and X_2= K_3 is low and X_3= K_4 is low then Y= UE ;

R_6: IF X_1= K_1 is low and X_2= K_2 is middle and X_3= K_3 is middle and X_4= K_4 is middle X_6= K_6 is middle and X_8= K_8 is middle then Y= SE ;

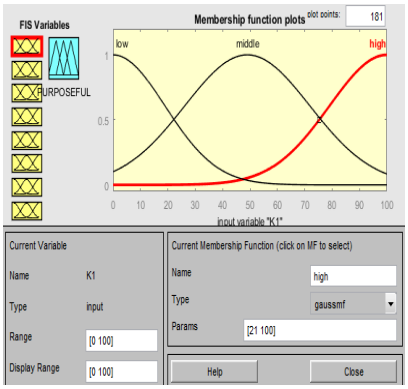

Figure 2. K_1 - belonging functions of the criterion of human flow passing through the object

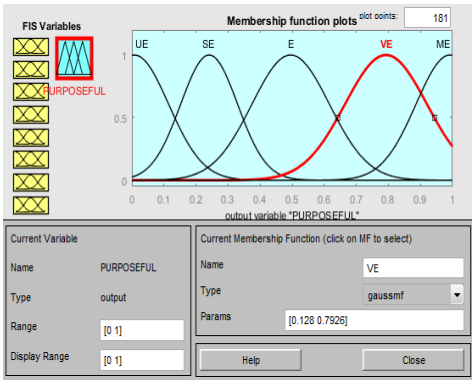

Figure 3. Appropriateness of the choice of alternatives Functions of the linguistic concept

The formula for calculating the membership functions $\mu_{R_i}(u)$ for each alternate (i = 1 ,6) for the left-hand sides of each rule is given below:

$$R_i: \mu_{L_i}(a) = \min\left\{\mu_{K_j}(a)\right\}, \text{(i=1÷6; j=1÷8)}$$

Finally, the rules can be summarized as follows:

R_1: if X= L_1 then Y= SE ;

R_2: if X= L_2 then Y= VE ;

R_3: if X= L_3 then Y= ME ;

R_4: if X= L_4 then Y= E ;

R_5: if X= L_5 then Y= UE ;

R_6: if X= L_6 then Y= SE ;

Based on this rule, the evaluation of the alternatives given in Table 2 was carried out in the notation MATLAB \ Fuzzy Inferences Systems [7, 8] (Figure 4). The created logical derivation module used minimum, maximum and centroid, respectively, as methods of implication, aggregation and defazification. Figure 5 graphically shows the flow of people passing by the K1 facility for 1 hour and the effect of the K6 parking rules on the final numerical evaluation of the alternatives in Figure 6 and Figure 7. As can be seen from the figures, the K1 and K6 criteria strongly influence the final decision.

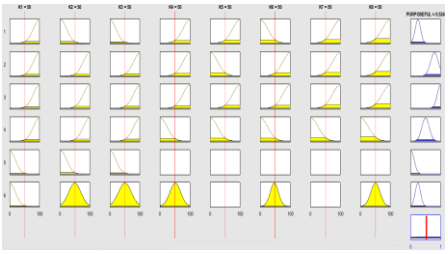

Fig. 4. Rules determining the dependence of the location of the trade object on the criteria.

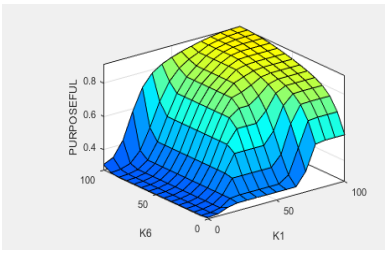

Fig. 5. Graphical interpretation of the effect of K1 and K2 criteria on the evaluation of alternatives

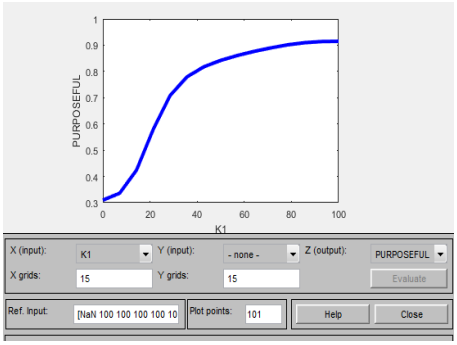

Figure 6. Dependence of the location of the object on the criterion of the flow of passers-by.

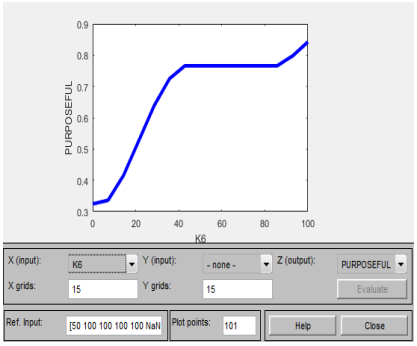

Figure 6. Dependence of the location of the facility on the criterion of the number of stops

CONCLUSION

The evaluation of the alternatives given in Table 2 in the notation MATLAB \ Fuzzy Inferences Systems described above allowed the following results to be obtained: for the alternative a_1 - Y_1= 0.8460; for the alternative a_2 - Y_2=0.8730; for the alternative a_3 – Y_3=0.8360. In descending order: $a_3 \rightarrow 0.8360 < a_1 \rightarrow 0.8460 < a_2 \rightarrow 0.8730$.

As you can see, the best object among these alternatives is the second object. Thus, as can be seen from Table 2, the majority of respondents noted that this object was

superior to the others in terms of both K1 and K6 criteria. Although the total score scores calculated in Table 2 are the same in all three alternatives. On the other hand, other criteria also have an advantage in the rules given by managers, and the alternative a2 is in some cases weaker than the alternatives a1 and a3 on these criteria.

The results obtained are more rhetorical, showing that in conditions of uncertainty, it is effective to evaluate the location of new branches and outlets in commercial enterprises on the basis of fuzzy set theory. On the other hand, it is useful to use fuzzy set theory when selecting the location of objects, instead of a simple scoring method, based on the knowledge and experience of managers, taking into account other simple but uncertain and difficult-to-formalize criteria and making judgments based on them. is reasonable and economically viable.

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