DECISION SUBSTANTIATION TO LOCATION A LOGISTICS CENTER THROUGH FUZZY SETS METHOD

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ABSTRACT

This paper uses the fuzzy set theory in analysis to location of logistics center on a national level area. The method relies on two key concepts: linguistic variables and fuzzy numbers. The location of logistics center decision is taking by three logistics managers from three organizations relying on five criteria which refer to: communication way access, terrains availability, infrastructure developed level, local and regional center positioning, and required investments.

In the first step logistics managers evaluate relative weight of criteria afterwards they evaluation of relative weight of each potential location to each criterion. In final, they selected the future location of the logistics center which obtains the highest value of the fuzzy opportunity index.

KEYWORDS: *linguistic variables, fuzzy sets, relative weights, potential location, logistics center, logistics managers, decision-makers, fuzzy opportunity index*

The fuzzy sets theory arise from necessity to modeling precisely, quantitative terms, the imprecisely naturals language which is formulate in words or sentences.

Imprecision is in connection with the complexity systems. A high level of the complexity decreases possibility of the precisely evaluation of the performances' systems. In this case any affirmation about performances' system must be fuzzy, the imprecision level increasing concomitant with complexity system.

Modern logistics systems are characterize by a high level of complexity. The array of organizations and connections between these, commodities flows which cover a global logistics area are just a few determinants which make difficult decision process.

Assuring continuity materials and products flows and enhancing the capacity of response to the customers' demands on the national logistics area, suppose identification the best location for a new logistics center building. Operations spectrum of this center include: splitting, grouping and consolidating unit load, palletizing and containerization, products dosage, packaging and labeling, and others logistics activities with value added.

The location of logistics center decision is taking by three logistics managers from three collaborative organizations. The principal evaluation criteria of the potential locations are:

- Accessibility to several communication ways (C_1);
- Availability of land for building a logistics center, respectively proximity from the communication ways, and the size of lot required for building both the center and the platforms for warehousing containers (C_2);
- The level of infrastructure development from area pursuit (C_3);
- Positioning in comparison to the local and regional distribution centers (C_4);

- Investments required (C_5), respectively:
  - cost of purchasing land (c_{1i});
  - labor cost (c_{2i});
  - cost of both purchasing required equipments and connecting to the existing infrastructure (c_{3i}) .

In linguistic terms, relative evaluations suppose assign a weight – very high (VH), high (H), medium (M), low (L), very low (L) – to each location criteria. Rely on attribute scale, settle in common accord, logistics managers can transform linguistic variables to numerical weight distribution (fig.1).

In the firs step decision-makers D_i (i=1,3) appreciate from qualitative point of view the relative weight of evaluation criteria C_j (j=1,5). The results are inserting in table 1.

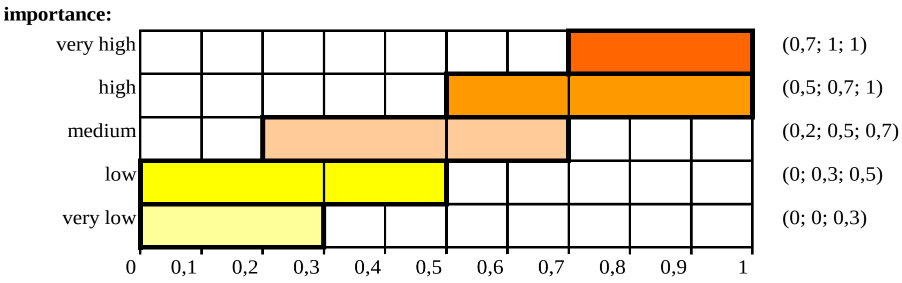

Fig. 1 - Numerical scale of linguistic variables

Relative weight of evaluation criteria assignment by the decision-makers

Table 1

C_j \ D_i	**D_1**	**D_2**	**D_3**
C_1	High	Very high	High
C_2	Very high	Medium	Medium
C_3	Medium	High	Low
C_4	Medium	High	High
C_5	High	Medium	Very high

From table 1 results that *positioning in comparison to the local and regional distribution centers (C_4)* represents a criterion with medium weight for one decision-maker and with high weight for others. At the same time, *accessibility to several communication ways (C_1)* represents a criterion with high weight for two decision-makers and with very high weight for other.

In the next step, the qualitative appreciations from table 1 are transposing in numerical weights, according to values from figure 1. Also, we calculate the average of these weights. Hereby, for criterion C_1, we obtain:

- lower bound:

$$(H + VH + H): 3 = (0,5 + 0,7 + 0,5): 3 = 0,567$$

- middle level:

$$(H + VH + H): 3 = (0,7 + 1 + 0,7): 3 = 0,8$$

- upper bound:

$$(H + VH + H): 3 = (1 + 1 + 1): 3 = 1$$

The weight distribution of the criterion C_1, considering the opinions' logistics managers, will be:

$$p_1 = (0,567; 0,8; 1)$$

Similarly proceeding for the other criteria will obtain the next weights distributions:

$$p_2 = (0,367; 0,667; 0,800)$$
$$p_3 = (0,233; 0,500; 0,733)$$
$$p_4 = (0,400; 0,633; 0,900)$$
$$p_5 = (0,467; 0,733; 0,900)$$

In the next step, logistics managers evaluate each possible location for positioning the logistics center in comparison to each five evaluation criteria. In our example, we have three available locations: L_1, L_2, L_3. The results of these evaluations are presented in tables 2-5.

Evaluation of possible locations for positioning the logistics center in comparison to criterion C_1

Table 2

L_i \ D_i	**D_1**	**D_2**	**D_3**
L_1	H	H	M
L_2	VH	VH	H
L_3	H	M	H

Evaluation of possible locations for positioning the logistics center in comparison to criterion C_2

Table 3

L_i \ D_i	**D_1**	**D_2**	**D_3**
L_1	H	H	M
L_2	VH	VH	H
L_3	H	M	H

Evaluation of possible locations for positioning the logistics center in comparison to criterion C3

Table 4

L_i \ D_i	**D1**	**D2**	**D3**
L_1	**H**	**M**	**H**
L_2	**M**	**L**	**H**
L_3	**H**	**M**	**M**

Evaluation of possible locations for positioning the logistics center in comparison to criterion C4

Table 5

L_i \ **D_i**	**D_1**	**D_2**	**D_3**
L_1	**VH**	**H**	**H**
L_2	**L**	**M**	**M**
L_3	**M**	**L**	**M**

According to values from figure 1, the qualitative evaluations of possible locations for positioning the logistics center L_i in comparison to criterion C_j are transposing to relative weights π_{ij}. Following the same procedure as before, we obtain the values presented in table 6.

Relative weights of possible locations for positioning the logistics center in comparison to evaluation criteria

Table 6

Criterion C_j	Relative weight π_{ij}
C_1	π_{11} = (0,400; 0,633; 0,900) π_{21} = (0,633; 0,900; 1) π_{31} = (0,400; 0,633; 0,900)
C_2	π_{12} = (0,567; 0,800; 1) π_{22} = (0,233; 0,500; 0,733) π_{32} = (0,400; 0,633; 0,900)
C_3	π_{13} = (0,400; 0,633; 0,900) π_{23} = (0,233; 0,500; 0,733) π_{33} = (0,300; 0,567; 0,800)
C_4	π_{14} = (0,567; 0,800; 1) π_{24} = (0,133; 0,433; 0,633) π_{34} = (0,067; 0,367; 0,567)

Due to its importance, the criterion of cost – C_5 will be treated separately. The decision-makers evaluate this criterion in independently manner on its three specific sub-criteria: cost of purchasing land (c_{1i}), labor cost (c_{2i}), and cost of both purchasing required equipments and connecting to the existing infrastructure (c_{3i}). Conventionally, the costs are related in monetary units, in a single, dimensionless, form. These costs are repartition on the three locations L_1, L_2, and L_3 in accordance with the distribution from table 7.

Costs necessary to positioning the new logistics center, in comparison to each location considered

Table 7

Location	Land cost [c_{1i}]	Labor cost [c_{2i}]	Equipments cost [c_{3i}]	Total cost [c_{ti}]
L_1	(50; 52; 54)	(18; 20; 22)	(28; 30; 32)	(96; 102; 108)
L_2	(42; 46; 48)	(15; 15; 15)	(30; 32; 34)	(87; 93; 97)
L_3	(34; 38; 40)	(10; 12; 44)	(40; 42; 44)	(84; 92; 98)

The essential condition is that location with the lowest costs should have the maximum rating. In this case is necessarily the inversion costs value. Thus, the relative total costs C_{ti}, for positioning the new logistics center on the location L_i is calculating with formula:

$$C_{ti} = \frac{1}{c_{ti} \cdot \sum_{i=1}^{n} \frac{1}{c_{ti}}} = \frac{1}{c_{ti} \cdot s_{ti}} \quad i = \overline{1,3}$$

where:

- c_{ti} representing the total costs categories, estimate from decision-makers, necessary to positioning the new logistics center into location considered;
- s_{ti} representing the sum of costs for each appreciation level.

In the table 8 are presenting the calculus elements of relative total costs C_{ti}, and its values for locations L_i.

Calculation of relative total costs for positioning the new logistics center, in comparison to each location considered

Table 8

	$1/c_{ti}$			$c^* = c_{ti} \cdot s_{ti}$			$C_{ti} = 1/c^*$		
L_1	0,0093	0,0098	0,0104	2,8582	3,2055	3,6521	0,2738	0,3120	0,3500
L_2	0,0103	0,0108	0,0115	2,5902	2,9226	3,2801	0,3050	0,3422	0,3861
L_3	0,0102	0,0109	0,0119	2,5009	2,8912	3,3139	0,3018	0,3460	0,4000
s_{ti}	***0,0298***	***0,0315***	***0,0338***						

Data from table 9, which complete the data from table 6, represent the relative weights (π_{ij}), specifics criterion C_5, which results from table 8:

Relative weights of possible locations for positioning the logistics center in comparison to evaluation criteria C_5

Table 9

Criterion C_j	Relative weight π_{ij}
C_5	π_{15} = (0,273; 0,312; 0,350) π_{25} = (0,305; 0,342; 0,386) π_{35} = (0,302; 0,346; 0,400)

For identification of fuzzy opportunity index, Ω_i, for positioning the new logistics center into location L_i, we calculate first the average values of relative weights locations, determining in comparison to relative weight of evaluation criteria.

This is give by:

$$\omega_i^{\xi} = \frac{1}{k}\sum_{j=1}^{5}\pi_{ij}^{\xi} \cdot p_j^{\xi} \qquad i = \overline{1,3}$$

where, ξ representing lower-, middle- or upper-bound of relative weights.

Thus,

$$\Omega_i = \sum_{i=1}^{n}\omega_i^{\xi} \qquad i = \overline{1,3}$$

For example, for location L_1 in comparison to those five reference criteria, we have:

$$\omega_1^i = \frac{1}{5}\cdot\left[(0,400\cdot 0,567)+(0,567\cdot 0,367)+(0,400\cdot 0,233)+(0,567\cdot 0,400)+(0,273\cdot 0,466)\right] = 0,176$$

Accomplish similar calculations we obtain:

$$\omega_1^m = 0,418 \text{ şi } \omega_1^s = 0,715$$

In table 10 we are centralized fuzzy opportunity indexes for each potential location for positioning the new logistics center.

Fuzzy opportunity indexes

Table 10

L_i	ω_i^{ξ}	Ω_i
L_1	(0,176; 0,418; 0,715)	**1,310**
L_2	(0,139; 0,366; 0,608)	1,113
L_3	(0,122; 0,340; 0,615)	1,077

From data analysis from table 10 results that the greatest index is obtain from location L_1, which is recommended for positioning the new logistics center.

The concepts of fuzzy numbers and linguistic variables are used to evaluate the specific criteria in such manner that the viewpoints of decision makers can expressed without any constraints. The fuzzy sets of decision algorithm used for location selection to positioning a logistics center, can also be computerized to make the implementation easier.

The advantages of fuzzy sets method consist in:

-there is no limit to the determinants that can be considered in a problem because the number of these does not affect the complexity of decision analysis;

-there is a multitude selection of words to express the exact evaluation, so it gives the decision-maker a large range of scales from which to choose.

The application of fuzzy sets theory even to a simple problem, requires knowledge about this theory, therefore the decision maker must be prepared before to use this method. This situation represents the principal disadvantage of the method.

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