Decision making on the location of the shopping center in a large urban agglomeration

Ildus S. Rizaev and Elza G. Takhavova

Kazan National Research Technical University named after A.N.Tupolev–KAI, 10, K.Marx str., Kazan, 420111, Russian Federation
isr4110@mail.ru

Abstract. The paper represents the approach to solve the problem to choose a place for new commercial centers in large cities. The decision of this problem depends on many factors and the task belongs to multi criterion problems. Besides that, usually, when the task is stated, input data in this case often has qualitative type. That is reason, which causes restriction for using classic mathematical optimization methods. The method of analytical hierarchy analysis is offered to solve the problem. The main stages of the offered approach are described in the paper. The main information and necessary parameters are represented which the decision making process is based on. This approach is implemented for the case when four sites were given to choose the best alternative. Forming estimations that are used to form recommendation are described. The approach described may be used to solve site placing problem for different new large objects in the city.

Keywords: Hierarchy Analysis, Criteria, Alternatives Importance Assessment.

1 Introduction

Nowadays modern cities are raising continually due to influx population from villages and small towns. Large cities attract people with the opportunity to find work or improve their living standards. As a result, to meet supply and demand for products it is needed to build new shopping centers. To reach high efficiency when constructing new shopping centers many factors should be taken into account [1-2].

Optimal placing of the commercial center is complicated problem when a wide set of parameters have to be taken into consideration. It includes such factor as life level of citizens, transport communications, location of concurrent, logistic etc. In general, we get multi criteria problem. Analytical methods can be used to solve such problems. Among them moving to some single global criterion may be used, for example, it may be getting maximal income. The method of compromises or linear programming and others may be implemented. However, their disadvantage is the inability to take into

account various factors, most of which cannot be represented by exact numerical values. A more appropriate approach in this case is the analytical hierarchy method using expert judgment [3-4].

2 Materials and methods

Usually, when a set of criterion and vagueness should be taken into account when decision making, perspective methods are decomposition methods on the base hierarchies analysis and fuzzy logics. It is possible to propose such an approach, based not on exact quantitative methods, but on the opinions of experts who use scales of preferences when making decisions. This is a method for analyzing hierarchies [5-7].

The difficulty in analyzing the hierarchy lies in determining the weights to evaluate the alternative solution. A pairwise comparison matrix is used in this case. If the number of criteria at a given level of the hierarchy is n, the pairwise comparison matrix $C(nxn)$ is determined by the elements c_{ij}. The numbers from 1 to 9 are used to represent the grades to assess the importance of the criteria number i relatively to criteria number j. If the value of c_{ij} is equal to 1, it means that criteria number i and criteria number j have equal importance. More the value of c_{ij}, more the importance of criteria number i in comparison with criteria number j. If the value of c_{ij} is equal to 9, it means that criteria number i is incomparably important in comparison with criteria number j. Additional condition for element c_{ij} is following: if the value of c_{ij} is equal to k, then the value of c_{ji} is equal to $1/k$. In the general case, there can be several levels of the hierarchy. At each level, the existence of an arbitrary number of criteria and an arbitrary number of alternatives $A1, ..., Ak$ is admissible. For clarity, a simpler diagram is shown in Fig. 1.

Hierarchy analysis method assumes decomposition of general problem onto simpler compounds. Hierarchy is being built beginning from setting general problem. The next levels of the hierarchy goals and criterion are indicated and the lowest level is the level of alternatives.

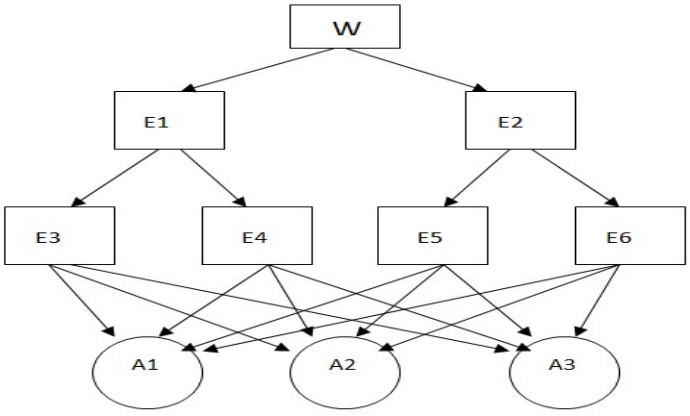

Fig. 1. Scheme of a hierarchy (Eij – hierarchy elements, Aj – alternatives).

Hierarchy analysis method assumes decomposition of general problem onto simpler compounds. Hierarchy is being built beginning from setting general problem. The next levels of the hierarchy goals and criterion are indicated and the lowest level is the level of alternatives.

Analytic hierarchy method assumes in the given statement implementation of the following stages [5; 8]. At the first stage, the problem is represented by the hierarchical structure with levels: goals – criterion - alternatives. The second stage lies in pair comparison for the elements of every level taking in account the nature of elements of the previous, higher level of according hierarchy. Comparative significance coefficients are shown in Table 1, using ten-point estimation scale.

Table 1. Comparative significance coefficients.

Level of significance	Value of coefficient
Equal significance	1
Temperate superiority	3
Essential or strong superiority	5
Significant superiority	7
Absolute superiority	9

Thus, the coefficients c_{ij} ($i,j=1,...,n$, $c_{ij}=1$) are set to take into account the comparative significance of the criteria. Pair comparison matrix is formed which has the inverse symmetry feature (1).

$$c_{ij} = 1/c_{ji} \tag{1}$$

Using c_{ij} the eigenvector for each criteria is calculated by means formula (2) and (3).

$$d_i = \prod_{j=1}^{n} c_{ij} \qquad i = 1,...,n \tag{2}$$

$$k_i = \sqrt[n]{d_i} \qquad i = 1,...,n \tag{3}$$

Importance coefficients are calculated using evaluated components of own vectors for any comparison matrix for the according level of the hierarchy for criterion and alternatives on formula (4).

$$\alpha_i = \frac{k_i}{\sum_{i=1}^{n} k_i}, \qquad i = 1,...,n. \tag{4}$$

Results of these procedures are formed in tables. Under such conditions the consistency of experts' opinions should be checked.

Let, accordingly to Figure 1, for the first level of the hierarchy the weights p and q assigned for elements E1 and E2, with conditions p≤1, q≤1, p+q=1. The weights for the next level of the hierarchy are following: for E3 it is equal p1, for E4 it is p2 and $p1+p2=1$. The weights for the level E4 is equal to q1, for E5 it is equal to q2 and $q1+q2=1$. When choosing alternatives at the upper level, the criteria are taken into account at the first level E1, E2 with weights p and q and at the next levels E3, E4 the weights will be p1, p2. For the E5 and E6 the weight will be q1 and q2, The choice of alternative A1 at the third lower level is set by the weights p31, p41, q51, q61, alternative A2 is set by the weights p32, p42, p52, p62 and alternative A3 - by p33, p43, q53, q63. Then to choose the alternative the next expressions are used (5).

$$\begin{aligned} W(A1) &= p(p1 \cdot p31 + p2 \cdot p41) + q(q1 \cdot q51 + q2 \cdot q61) \\ W(A2) &= p(p1 \cdot p32 + p2 \cdot p42) + q(q1 \cdot q52 + q2 \cdot q62) \\ W(A3) &= p(p1 \cdot p33 + p2 \cdot p43) + q(q1 \cdot q53 + q2 \cdot q63) \end{aligned} \tag{5}$$

The alternative should be chosen is those that gets maximal weight W.

3 Results

The problem was stated to place a new commercial center, which must serve the set of smaller seller. It is necessary to choose the appropriate place for the commercial center. Let, the alternatives "A", "B", "C" and "D" are to be analyzed. The following criterion and were chosen:

- The medium of salary in the region (c1).
- Having satisfactory transport communication (c2).
- Having qualified labor resources (c3).
- The presence of competitors (c4).
- Close to warehouses (c5).
- The volume of sales market (c6).

The goal is to choose the best alternative to place ырщззштп center that provides the minimal expenditure for logistic under condition of optimal values of listed above criterion. In this case, the hierarchical structure in Fig. 2 represents the problem. Table 2 shows results of evaluation given by experts.

The similar way is used to assess the results of comparison alternatives of pairs for every criteria. Table 3 shows results for the criteria C1. Calculated results in Table 4 represent assessment of importance for alternatives

Assessment of alternative priority is calculated by means summarization of production criteria importance and of alternative importance coefficient for each alternative. Let, Wi is alternative priority, i=1,2,3,4.

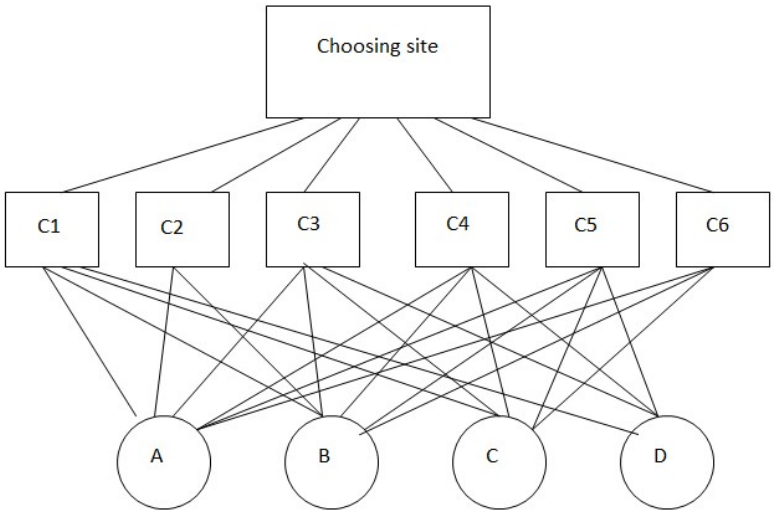

Fig. 2. The scheme for the problem of choosing place for the shopping center.

Table 2. Evaluation for pair comparison of criteria.

Criteria	C1	C2	C3	C4	C5	C6
C1	1	3	1	2	0.5	0.5
C2	0.3333	1	0.5	2	0.3333	0.3333
C3	1	2	1	0.5	0.25	0.1666,
C4	0.5	0.5	2	1	0.25	0.25
C5	*2*	3	4	4	1	1
C6	*2*	3	6	4	1	1

Table 3. Pair comparison assessment for criteria C1.

Alternative	"A"	"B"	"C"	"D"
Site "A"	1	0.2	0.25	0.1666
Site "B"	5	1	0.3333	0.5
Site "C"	8	3	3	2
Site "D"	*6*	2	0.5	1

Assessment of alternative priority is calculated by means summarization of production criteria importance and of alternative importance coefficient for each alternative. Let, *Wi* is alternative priority, *i*=1,2,3,4.

W1=0.148×4.7+0.797×40+0.814×40.6+0.776×58.2+0.2965×58.2+0.3167×53.2≈46;

W2=0.148×17.7+0.797×43+0.814×40.6+0.776×28.7+0.2965×29+0.3167×31.3≈30;

W3=0.148×48.7+0.797×5.4+0.814×4.9+0.776×5.2+0.2965×8.5+0.3167×6.1≈13;

W4=0.148×28.91+0.797×11.6+0.814×13.9+0.776×7.9+0.2965×4.2+0.3167×9.4≈11;
After evaluation sites “A”, “B”, “C”, and “D” the following results are obtained:

1. Site “A” - 46%;
2. Site “B” - 30%;
3. Site “C” - 13%;
4. Site “D” - 11%.

Therefore, from the view point of using combined criterion, the most appropriate site to be recommended is site “A”.

Table 4. Evaluation of alternative importance according to criteria.

Criteria	C1	C2	C3	C4	C5	C6
Importance	14.8	7.97	8.14	7.76	29.65	31.67
Site “A”	4.7	40	40.6	28.7	29	31.3
Site “B”	17.7	43	40.6	0.5	0.25	0.1666,
Site “C”	48.7	5.4	4.9	5.2	8.5	6.1
Site “D”	28.91	11.6	13.9	7.9	4.2	9.4

4 Discussion

As it is indicated in [1], an urban agglomeration is a compact arrangement of settlements with industrial, transport and cultural links. Each shopping center has its own service area. Usually, the following types of services take place: microdistrict, district, regional, distinguished by their service area and availability. Studies of cities with a million-plus population in the Russian Federation have shown that a number of cities do not have a sufficient number of shopping centers, with low forms of trade. There are cities with more developed trading floors. In any case, cities are growing and the need to create new shopping centers always appears, and accordingly the problem of location arises. The placement problem cannot be solved by a decree from above, since an unsuccessful location can lead to unprofitability of the shopping center and, accordingly, to large losses. Since this task is due to many dependent factors, then a mathematical approach is required to solve it, the most acceptable is the method of analyzing hierarchies. A similar approach has been used to choose the location of the waste incineration plant in Kazan [9-10]. The approach described e can be used when the construction of any major project: they may be construction of a new factory, airport, stadium, etc. e construction of any major project: Construction of a new factory, airport, stadium, etc., etc.

5 Conclusion

The problem of placing new commercial centers in the city agglomeration has been considered. Different factors, many of which are not exactly evaluated by quantitative values, influence on decision. They are alternative sites to be available, transport

communication, solvency of the population and others. Moreover, the problem demands considering not a single, but a set of criteria. To solve the stated problem analytical hierarchy analysis is implemented to choose the most appropriate alternative between four possible sites. This approach is based on the opinion of experts and doesn't guarantee exactly optimal decision, but it provide quite acceptable choice.

References

1. Imangalin A.F.: Forecast of the location of shopping centers in large Russian agglomerations. Moscow University Bulletin, series 5 Geography, 4, 62-68 (2013).
2. Antonov A.: System analysis. "Higher School", Moscow (2004).
3. Brodetsky G.L., Terentyev P.A.: Application of the analytical hierarchy method to optimize the location of the regional distribution center. Logistic technology, 1(6), 26-34, HSE University, Moscow (2005).
4. Steuer R.E.: Multiple Criteria Optimization: Theory, Computations and Application. Wiley. New York (1986).
5. Drake P.: Using the Analytic Hierarchy Process in Engineering Education. International Journal of Engineering Education, 14(3), 191-196 (1998).
6. Taha, Hamdi A.: Introduction to Operations Research. Publishing house "Williams", Moscow (2001).
7. Saaty T., Kearns K.: Analytical Planning System Organization. Radio and Communication, Moscow (1991).
8. Saaty T.: Rank generation, preservation, and reversal in the Analytic Hierarchy Decision Process. Journal of the Decision Sciences Institute, 18(2) (1987).
9. Rizaev I.S., Takhavova E.G.: Hierarchy Analysis Technique in Solving the Problem of Choosing a Place to Build the Incinerator Plant. IOP Conference Series: Earth and Environmental Science, 459, 2 (2020).
10. Moiseeva T., Wissarionova L.: Application of hierarchy analysis approach to the characterization of eco-trails in the National Park "Paanayarvi". Principles of ecology, 3(1), 15-24 (2014).