Methods and means of determining the optimal location of industrial enterprises

V V Sosedko, A G Yanishevskaya
Omsk State Technical University, 11, Mira Ave., Omsk, 644050, Russian Federation

Abstract. The article considers the problem of choice the location of an industrial enterprise (production facilities, storage facilities and technical personnel). To solve this problem, the methods and means of determining the optimal location of the industrial enterprise, allowing for a comprehensive analysis based on various factors affecting the location of the enterprise. The task of determining the location for the production area of the enterprise is choice of the most optimal option, from the proposed on the basis of a number of methods. The methods of determination include: the method of weighing, the method of placement taking into account the total cost, the gravitational method, the method of cost calculation. Analytical studies and results after solving problems using each method. In General, the article solves the problem of choosing the location of industrial areas of the enterprise on the basis of different requirements for the created enterprise or its structural unit located in the region.

1. Introduction

There are a number of factors which determines the effective operation of industrial enterprises. One of these factors is the optimal location of the enterprise in the region and its structural subdivisions [1, 2]. The optimal location of the enterprise in the region (including at the level of the Federal district) is determined on the basis of geo-economic specifics, and in the locality - can significantly reduce the cost of transportation of raw materials and purchased components, as well as finished products, optimizing work with suppliers, sales companies and customers [3, 4].

2. Problem Statement

Tasks to determine the optimal location of enterprises, their components - branches, production facilities, are very nontrivial due to the lack of uniform rules and clear algorithms for enterprises of various fields of activity. As a result, you can apply your most appropriate criteria to each business, which is key to selecting a location. These criteria include: the minimum time of availability of the enterprise, the minimum distance, the maximum availability for the client. It should be noted that not always, the minimum distance means minimum availability time or maximum availability for customers, but in most cases, these criteria are interrelated [5]. The appropriate method is selected from the priority criterion for the solution [6]. In this case, there are such groups of methods as logistics, discrete mathematics and simulation methods.

Geoinformation technologies are the most suitable for determining the location of enterprises [7]. They provide an opportunity to expand the possibilities of mathematical methods. These methods include the method of weighing, the method of placement taking into account the total cost, the gravitational method, the method of cost calculation [8].

The main objective of this article is to determine the location of the enterprise using these methods, to analyze and compare the results obtained by different methods.
3. Theory

The solution to the problem of location of enterprises is associated with the determination of the most optimal geographical places in the limit of a large region or settlement. Making the right decision about the location of the company is very important, as it can greatly affect the results of its activities in the coming years. Not necessarily a good location guarantees success, but a bad location can definitely lead to failure in the future. Often, however, management does not take into account that such decisions are long-term, and make the choice of the place, based on short-term benefits.

In the process of solving the problem of production location, it is necessary to choose the best one from several placement options. To do this, there are a number of simple methods for solving these problems. These methods: method of weighing, placement method taking into account the full costs of the gravitational method, method of costing.

The weighting method primarily takes into account the factors that are most important for placement, but not always subject to representation in numerical form. The difference between the factors is expressed in the accrual of points. First, a number of factors are determined that primarily affect the location of the enterprise, and to determine the relative importance of each factor is given a weight determined by the number of the segment [0, 1]. The sum of all weights should be equal to one. Next, set the scale of measurement to find each factor and for each of the proposed placement is evaluated all the factors on the selected scale.

The method of placement taking into account the full cost involves an analysis of the company's production costs and volumes of products. On the basis of certain fixed and variable costs (based on the calculation per unit of output) is considered a variant of the location of production, with the lowest total cost of production.

The gravitational method can be applied to accommodate the head enterprise working with several branches. Draw branches on the coordinate plane of the Oxy. Let \((x_i, y_i)\) be the coordinates of the i-th branch, \(w_i\)-volume of product orders transferred to the i-th branch \((i = 1, \ldots, n)\). In this case, the company must be placed in the so-called center of gravity—a point with coordinates \((C_x, C_y)\),

where

\[
C_x = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}; \quad C_y = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \tag{1}
\]

Using the costing method, you operate only on freight costs to select the location of an enterprise that works with multiple branches from the options.

Draw branches on the coordinate plane of the Oxy. Let \((x_i, y_i)\) - coordinates of the i-th branch, \(w_i\)-number of daily deliveries to the i-th branch of materials and components. \((i=1, \ldots, n)\), \((x_0^j, y_0^j)\) - coordinates of the j-th possible location of the trading house \((j=1, \ldots, m)\).

Select the j-th option for which the sum of

\[
\sum_{i=1}^{n} w_i \left( |x_i - x_j| + |y_i - y_j| \right) \tag{2}
\]

is the smallest.
4. Experimental Result

When determining the location of the enterprise by weighing determine the factors affecting the placement.

1 Availability for customers and partners. In this case, we are talking about the availability of the enterprise for contacts with these persons-both existing and potential new partners and customers, the opportunity to meet quickly, to negotiate, etc.;

2 Availability for suppliers (maintenance of office equipment and software, equipment, tools and components, courier services). The impact of this factor, based on the specific organizations selected as suppliers, may differ from the previous one;

3 Availability of contractors (third-party companies that perform production orders, such as the manufacture of parts, printed circuit boards, printing services) in case of impossibility of certain operations in the enterprise, suppliers (including specialized stores). In this case, the degree of influence is determined by the specifics of the enterprise and contractors-a great influence is the presence of organizations engaged in the necessary activity, which are within walking distance and meet the requirements;

4 Rent. For this factor plays a role not only the amount but also the package of services and conditions provided by the landlord (rent, security, cleaning, payment of utilities such as electricity, Internet);

5 Availability for employees (travel by public transport and private cars, access routes, the ability to eat at lunchtime at the enterprise or the presence of a number of catering enterprises, the development of infrastructure near the enterprise, including pharmacies, gas stations, shops, etc.).

6 Meeting the requirements for the premises (availability of office places, welcome paved local area network, designated as a warehouse for the storage of materials, spare parts and other inventory items, equipped with ventilation facilities, functioning toilets, heating, good cell phone coverage).

When solving the problem of choosing the location of the enterprise, 3 options were proposed in 3 districts of the city:
A-in the city center, on the main street;
B-in the city center, at some distance from the Central highway;
C-in the area located on the outskirts of the city.

All data are shown in table 1.

| Factor                                | Weight | Variants of the location of the enterprise |
|---------------------------------------|--------|-------------------------------------------|
|                                       |        | A  | B  | C  |
| 1 Availability for customers and partners | 0.10   | 10 | 9  | 6  |
| 2 Availability for suppliers          | 0.15   | 10 | 9  | 6  |
| 3 Availability of counterparties      | 0.18   | 9  | 10 | 8  |
| 4 Rent                                | 0.20   | 4  | 5  | 6  |
| 5 Accessibility for employees         | 0.20   | 9  | 8  | 5  |
| 6 Meeting the requirements of the room| 0.17   | 5  | 5  | 7  |

Based on the results of the study of options, the factor weight is multiplied by the measured factor for each option, then the obtained values are summed for each option, and the final version of the
enterprise location with the greatest result is submitted for consideration. In this case, it is variant B (result 7.24) with a building located in the city center, at some distance from the Central highway (see table 2).

| Table 2. The Measured Factors For Each Enterprise | Variants of the location of the enterprise | Weight x A | Weight x B | Weight x C |
|---------------------------------------------------|------------------------------------------|------------|------------|------------|
| Factor 1: Availability for customers and partners  | A: 0.10, B: 4, C: 3                    | 0.40       | 0.40       | 0.30       |
| Factor 2: Availability for suppliers               | A: 0.15, B: 5, C: 4                    | 0.75       | 0.75       | 0.60       |
| Factor 3: Availability of counterparties           | A: 0.18, B: 7, C: 6                    | 1.26       | 1.44       | 1.08       |
| Factor 4: Rent                                     | A: 0.20, B: 7, C: 10                   | 1.40       | 1.80       | 2.00       |
| Factor 5: Accessibility for employees              | A: 0.20, B: 9, C: 10                   | 1.80       | 2.00       | 1.40       |
| Factor 6: Meeting the requirements of the room     | A: 0.17, B: 5, C: 7                    | 0.85       | 0.85       | 1.19       |
| Factor 7: Availability for customers and partners  | A: 1.00                                 | –          | –          | –          |

In the process of solving the problem of placing production through the method of placement with full cost were found fixed and variable costs (based on the unit of output) in each of the settlements: A, B and C. After that, were found places to place the production taking into account the total cost. The data obtained are presented in table 3. Fixed costs consist of the cost of rent, utilities, payroll and other fixed costs. Variable costs are determined by the type of products, technological readiness of the enterprise, associated costs, including the cost of materials and components for the production unit.

| Table 3. The Results of Solving the Problem of Placement of Production Through Placement Method Taking Into Account the Full Cost | The constant costs, thousand RUB. | Variable costs per unit of production, thousand RUB. | The expected annual production vol. | Results, thousand RUB. |
|-------------------------------------------------------------------------------------------------------------------------|----------------------------------|-----------------------------------------------------|-------------------------------------|------------------------|
| Nº of variant | A | B | C | A | B | C | 1000 | 900 | 850 | 20 | A | B | C | 22115 | 19060 | 17625 |
| 1 | 2115 | 1060 | 625 | 1000 | 900 | 850 | 20 | 22115 | 19060 | 17625 |
| 2 | 2135 | 1055 | 630 | 1000 | 900 | 850 | 20 | 22115 | 19060 | 17625 |
| 3 | 2120 | 1065 | 640 | 1000 | 900 | 850 | 20 | 22115 | 19060 | 17625 |
| 4 | 2100 | 1000 | 650 | 20 | 15 | 10 | 100 | 5135 | 3555 | 3130 |
| 5 | 2200 | 1050 | 635 | 100 | 74 | 43 | 250 | 12100 | 8600 | 5650 |

Naturally, in the process of making such decisions, the data found should be taken as starting. This requires a more in-depth analysis of costs, production plans, and other significant factors.

When calculating the optimal location of the enterprise by the gravitational method, it is supposed to create a centralized enterprise to work with branches A, B, C, D. The results of the calculation are given in table 4.

| Table 4. The Results of Calculating the Optimal Location of the Enterprise by Gravity | Branch | Coordinate | Number of trips from the Central enterprise to the branch per day |
|--------------------------------------------------------------------------------------|--------|-------------|---------------------------------------------------------------|
|                                                                                     | A      | (8,10)      | 2                                                             |
|                                                                                     | B      | (7,5)       | 5                                                             |
|                                                                                     | C      | (3,6)       | 4                                                             |
Calculate the coordinates of the center of gravity to accommodate the Central enterprise.

\[
C_x = \frac{(8 \times 2 + 7 \times 5 + 3 \times 4 + 2 \times 3)}{(2 + 5 + 4 + 3)} = 4.9
\]
\[
C_y = \frac{(10 \times 2 + 5 \times 5 + 6 \times 4 + 8 \times 3)}{(2 + 5 + 4 + 3)} = 6.6
\]

Answer: (4.9; 6.6).

The main drawback for this method is that the location found in this way can be in a geographically difficult to access place (for example, in a reservoir, in a mountainous or forest area, at the intersection of Railways). Therefore, the most appropriate option is chosen first by determining the places available for placement, and then by using the methods of weighing, full-cost allocation or costing.

In solving this problem by costing the choice of location of the branch is carried out from two possible options, for example: (5, 7) and (4, 8).

Data for option (5, 7) are shown in table 5.

**Table 5. The Result for Option (5, 7)**

| Branch | \(x_i\) | \(y_i\) | \(w_i\) | \(|x_i - 5|\) | \(|y_i - 7|\) | \(|x_i - 5| + |y_i - 7|\) | \(w_i(|x_i - 5| + |y_i - 7|)\) |
|--------|--------|--------|--------|-------------|-------------|-----------------|------------------|
| A      | 8      | 10     | 2      | 3           | 3           | 6               | 12               |
| B      | 7      | 5      | 5      | 2           | 2           | 4               | 20               |
| C      | 3      | 6      | 4      | 2           | 1           | 3               | 12               |
| D      | 2      | 8      | 3      | 3           | 1           | 4               | 12               |
| **Total** | **56** |        |        |             |             |                 |                  |

The values of columns 1 through 4 are specified in the initial condition. The numbers in the 5-th and 6-th columns are determined by the subtraction module from the values of the 2-nd and 3-rd columns, respectively, the values \((x_0 = 5)\) and \((y_0 = 7)\). The 7-th column is the sum of the values of the 5-th and 6-th columns. In 8-th column is written the work of the 4-th and 7-th columns. In the last row the sum of the numbers of the 8-th column is calculated.

Similarly, the data filled in for option (4, 8) are given in table 6.

**Table 6. The Result of the Decision is for Option (4, 8)**

| Branch | \(x_i\) | \(y_i\) | \(w_i\) | \(|x_i - 4|\) | \(|y_i - 8|\) | \(|x_i - 4| + |y_i - 8|\) | \(w_i(|x_i - 4| + |y_i - 8|)\) |
|--------|--------|--------|--------|-------------|-------------|-----------------|------------------|
| A      | 8      | 10     | 2      | 4           | 2           | 6               | 12               |
| B      | 7      | 5      | 5      | 3           | 3           | 6               | 30               |
| C      | 3      | 6      | 4      | 1           | 2           | 3               | 12               |
| D      | 2      | 8      | 3      | 2           | 0           | 2               | 6                |
| A      | 8      | 10     | 2      | 4           | 2           | 6               | 12               |
| **Total** | **60** |        |        |             |             |                 |                  |

Since 56 < 60, then the most appropriate option is (4, 7).

In practice, of course, in the decision-making process about the choice of location takes into account other factors, but it is not necessary to ignore the results.

5. Discussion of Results

In the process of solving the problem of calculating the optimal location of the enterprise, various methods were considered: weighing, placement method taking into account the total cost, gravity method, cost calculation method. The most suitable for this task is the method of weighing, taking into account a number of important factors affecting the choice of the location of the enterprise. The
method of placement taking into account the full cost allows you to take into account the fixed and variable costs associated with the planned volume of output. The applied gravitational method does not take into account the peculiarities of the terrain, but at the initial setting of the available places it allows to find the most suitable option in terms of the distance between the enterprise and its branches. The costing method takes into account only the costs associated with the transportation of materials, components and manufactured products.

6. Conclusions and Conclusion

Application of the methods listed in the article, allow to find the optimal location of an industrial enterprise or its structural units, based on the selected key criteria. At the same time, to obtain the best results, it is necessary to compare the solutions found using different methods and take into account the peculiarities of the region, the locality, the presence of competitors and other factors. To solve this problem, the most appropriate method is the method of weighing, taking into account the factors that are most important for the location of the enterprise. As a result of the calculation, the most appropriate option among the proposed options is the location in the city center at some distance from the central highways.

Source of funding - at their own expense

References

[1] Wensheng W and Qingyang Z 2010 International Conference on Logistics Systems and Intelligent Management (ICLSIM). Studies on supply logistics distribution center location based on principal component analysis for coal enterprise vol 1 pp 212 – 215
[2] Weibing W, Guangjun Y, Yun Z and Jian W 2011 Seventh International Conference on Natural Computation. Multi-objective plant location decision model from the view of entire supply chain vol 3 pp 1256 – 1259
[3] Kazaeva M A 2012 Volga scientific journal. Application of simulation modeling for siting of enterprises on the geographical territory 5 20-23
[4] Oksanych I G, Petrenko V R, Kostenko A P and Galkin M A 2008 New Technologies Model of territorial location of service objects 4(64)
[5] Szymańska A I and Plaziak M 2014 Procedia - Social and Behavioral Sciences 110 381-9;
[6] Lackes R and Siepermann M 2009 Optimal Location Planning for Self-Storage Enterprises Computer Aided Chemical Engineering 27 2115-20
[7] Dulesov A S and Kazaeva M A 2011 Problems of modern economy: collection of materials IV International scientific and practical conference: in 2 parts. Part 2. Geoinformation technology for spatial location of objects of small business (Novosibirsk NGTU) pp 70-73
[8] Dulesov A S and Prutovych M A 2012 Algorithms of territorial placement of the enterprise on the basis of geoinformation technologies Applied informatics 5 14-21