Multinational Corporation Location Plan under Multiple Factors

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Abstract. With globalization, the international standards of the companies have varied a lot. When a company wants to open new international branch companies, a suitable model has to be formulated so that the specific number and the location of each company can be optimally determined. In this paper, we try to contribute to such effort. First, a multi-objective programming is established to be based on main influencing factors such as each city’s economic level. Then an adaptive particle swarm optimization model is utilized to locate branch companies. Due to constant renovation of communication mode, a set covering model is built by new influence factors such as submarine cable communication. Finally, using the penalty function ant colony optimization algorithm obtains an approximate optimal solution. The experimental results effectively demonstrate the proposed models’ feasibility, power, and usefulness.

1. Introduction

With the development of globalization, more and more companies are considering expanding the company’s market overseas. However, when multinational companies choose to open overseas branch addresses, they need to consider the limitations of many impact factors such as global communications, population density, economic factors and language types. These factors will affect the development of multinational companies overseas. Therefore, multinational companies should carefully consider the location of branch companies, because the convenient communication environment, economic development and other factors determine whether the company can successfully achieve globalization.

The location selection problem has been developed over a long period of time. The study of modern location problems began in 1909 and stems from the famous Weber problem$^1$. Since Kantorovich$^2$ proposed the linear programming problem in 1939, linear programming$^3$ has been fully applied to the location problem. After the continuous exploration of the location problem, Roth and Toregas$^4$ first proposed the set covering problem$^5$, which made it better to solve some difficult location problems. Later, for setting covering problem, many scholars had proposed various
algorithms using different ideas. Caprara\(^6\) compared several complete algorithms and proposed the CPLEX\(^7\) algorithm to solve the set covering problem.

In this paper, the adaptive particle swarm optimization (APSO) algorithm\(^8\) and penalty function ant colony optimization (PFACO) algorithm\(^9\) are used to solve the problem of multinational company's location and attain the optimal location. Using the influence of various factors on the location of the company, a multi-objective programming\(^{10}\) model based on APSO algorithm is established to ensure that the location of the site has certain advantages in all factors. Then, considering the impact of the global communication change and the complexity of its nature, we further analyze the distribution of the location based on the PFACO algorithm to make the company's development closer to globalization.

2. An APSO model for address selection

2.1 Multi-objective programming for expanding international influence

To ensure the company as international as possible, we firstly need to consider the economic level, population density, impact range and the number of users in various languages which are regarded as the impact factors. Moreover, in order to find all the cities with the largest possible impact factors, we could use the method of multi-objective programing to obtain a rational site selection plan. Based on the analysis above, we can get the following multi-objective programming model:

\[
\begin{align*}
\text{max} & \left\{ f_1(x), f_2(x) \right\} \\
\text{s.t} & \quad \begin{cases}
    x_i = \begin{cases}
        0 & \text{for city } i, \\
        1 & \text{for city } i \text{ is selected,}
    \end{cases} \\
    \sum_{i=1}^{n} x_i = SC \\
    \sum_{i=1}^{m} e_i \geq 10
\end{cases}
\end{align*}
\]

where \(x_i\) is the construction office for city \(i\), \(k_i^e\) is the economic factor for city \(i\), \(n_i^p\) is the population density factor for city \(i\), \(p_i^r\) is the impact range factor for city \(i\), \(q_i^l\) the number of people using the first language for city \(i\), \(SC\) is the number of selection city, \(e_i\) is the language usage type for city \(i\).

For this multi-objective programming problem, we solve it based on adaptive particle swarm optimization algorithm. Above all, an initial population of size \(N\) is randomly generated. Then we set each particle's position vector \(x_i\) and velocity vector \(v_i\). Next, we need to check whether each position vector satisfies the constraints. If it does not meet the constraints, then we should do some changes to meet the constraints.

The adaptive particle swarm optimization formula is as follows:
\[ r^T_k = \left\{ \sum_{i=1}^{n} \left[ \Theta_{f_k}(x^T_i - \bar{x}^T_i) \right] \right\}^\beta \]

and

\[ \{ r^{T\text{max}} = \max \{ r^T_k \mid k \in X^T \} \]
\[ r^{T\text{min}} = \min \{ r^T_k \mid k \in X^T \} \]

where \( \beta \) is a positive real number, \( r^T_k \) is the ideal distance between the individual \( k \) in the \( T \) generation and the current population, \( r^{T\text{max}} \) is the maximum ideal distance of the current population, while \( r^{T\text{min}} \) is the minimum ideal distance.

According to the formula above, it can be seen that the fitness for the individual \( k \) in the generation of population \( T \) is:

\[ F^T_k = \frac{r^{T\text{max}} - r^T_k + e}{(r^{T\text{max}} - r^{T\text{min}} + e)} \]

Finally, the global optimal solution of particle is updated due to the particle fitness value, that is, the global optimal solution of the whole particle swarm is:

\[ x_g = [x_{g1}, x_{g2}, \ldots, x_{gi}] \]

Using programming software, we can obtain the approximate optimal solution of adaptive particle swarm optimization algorithm.

The specific results are as Figure 1:

**Figure 1. Pareto front diagram**

It can be seen from the figure that the Pareto curve is close to smooth when the number of iterations of PSO is reached, which shows that this multi-objective programming model has an approximate optimal solution.

### 2.2 Exploring the changes in the location of international offices over time

When considering the short-term site selection problem, we do not need to consider the change of impact factors which could extremely affect the model of the site selection result, because these impact factors remain basically unchanged in a short time. But if we want to have a specific location plan, we have to set \( SC \) as a concrete number for the multinational corporation. Hence, now we suppose eight cities are to be established as short-term site selection location. Since the short-term factors are basically the same, we can see that the short-term city location is consistent with the current site selection.

For long-term site selection, we consider that various factors will change in the future such as changes in the number of users in various languages, economic level, population density, and impact range over time. Therefore, we reanalyze economic factors, population density factors, impact range and languages of use in the next 50 years. We choose to adopt the three exponential smoothing method.
to fit the influencing factors to attain their change results over time. According to the cubic curve smoothing formula, we can get the following model\textsuperscript{[11]}:

\[ x_{t+2} = a_t + b_t T + c_t T^2 \quad T = 1, 2, \ldots \]  

where

\[
\begin{align*}
\alpha_t &= 3S_t^{(1)} - 3S_t^{(2)} + S_t^{(3)} \\
\beta_t &= \frac{\alpha}{2(1-\alpha)^2} [5S_t^{(1)} - 2S_t^{(2)} + S_t^{(3)}] \\
\gamma_t &= \frac{\alpha^2}{2(1-\alpha)^2} [S_t^{(1)} - 2S_t^{(2)} + S_t^{(3)}]
\end{align*}
\]

where \(\alpha = 0.1\) and the initial value \(S_1^{(1)} = S_1^{(2)} = S_1^{(3)} = (x_1 + x_2 + x_3)/3\).

we can get its specific prediction model is:

\[ x_{t+2} = \sum_{i=0}^{2} a_t^i T^i \quad T = 1, 2, 3, \ldots \]  

The following table shows the coefficients that can be obtained for each impact factor:

| Impact factor                              | \(a_0\) | \(a_1\) | \(a_2\) | \(R^2\) |
|-------------------------------------------|---------|---------|---------|---------|
| Economic level                            | 34.8    | 0.06    | 0.24    | 0.97    |
| Population density                       | 81.3    | 0.20    | 0.03    | 0.92    |
| Impact range                              | 74.2    | 3.13    | 0.55    | 0.98    |
| The number of users in various languages  | 62.7    | 1.92    | 3.37    | 0.95    |

We can see that the growth of the four influencing factors meet with certain trends, and the coefficient \(R^2\) is close to 1. It indicates that the model is accurate and the regression effect is significant.

3. Set covering model based on submarine cable distribution

Compared to satellite communications systems, submarine cable communication system has dramatically improved transmission capacity, reliability and quality. Therefore, with the development of submarine cables, it has had a significant impact on the nature of global communications. Considering the importance of communications systems on international company location option, we need to restart selecting new location of the international companies. Moreover, in order to make each office's location as much as possible to serve a larger area and save resources, we use a set covering model to reconsider the location of the companies and reduce the number of them.

To facilitate a better application of the set covering model, we classified the possible languages in each city based on different linguistic lines\textsuperscript{[12]}. According to each city on the other cities cable connection, we come to the following set:

\[ S_i = \{ e_1, e_2, \ldots, e_m, d_{i1}, d_{i2}, \ldots, d_{in} \} \]

where, \(S_i\) denotes the set of city \(i\), \(e_i\) denotes whether the city \(i\) has the language \(m\), and \(d_{in}\) denotes whether there is a direct connection between the city \(i\) and city \(n\).

Based on the set cover model, we can draw the following goal planning model:
\[
\begin{align*}
\min \sum_{i=1}^{n} y_i \\
\text{s.t} \quad \sum_{i}^{n} S_i y_i \geq 1 \\
y_i \in \{0 \text{ or } 1\}
\end{align*}
\]

where, \( y_i \) denotes whether the city \( i \) to establish an international office.

In order to solve the optimization problem of set covering, we use the PFACO algorithm (Penalty Function Ant Acolony Optimization) to solve it.

\[
\eta^k = \frac{|D_k \cup S_i|}{z} \tag{10}
\]

where \( D_k \) denotes the current solution set obtained by the ant \( k \). \( z \) is the total number of elements

The subsets of the next selection of the ant \( k \) should be selected from the union of the obtained subsets and the elements of the current solution set. So, priority should be given to the subset of more elements. The probability of ants \( k \) moving from the current subset to the next subset is:

\[
p^k_i = \begin{cases} 
\tau_i^\alpha \left( \frac{|D_k \cup S_i|}{z} \right)^\beta / \sum_{u \in h} \tau_u^\alpha \left( \frac{|D_k \cup S_u|}{z} \right)^\beta, & \text{if } i \in h \\
0, & \text{else}
\end{cases} \tag{11}
\]

where \( \tau_i \) represents the number of pheromones left on subset \( S_i \). \( h \) is a set of subsets that have not yet been reached in the loop.

4. Experiment

We can find our location results based on adaptive particle swarm optimization algorithm. The site selection results as shown Figure 2:

![Figure 2. Short-term world site distribution](image)

Then, we put the related variables into the multi-objective programming model based on particle swarm optimization algorithm. Then, the distribution of cities for offices after 50 years can be found as Figure 3:
After comparing the two sites, we can see that Moscow and Dubai in short-term sites will be replaced by Mumbai and Johannesburg.

In order to reach the global approximate optimal solution as much as possible, we set heuristic factor $\alpha=100$. Then we find heuristic factor $\beta=\alpha$. Finally, we can get a better plan for the location of the city as Figure 4.

5. Conclusions
In this paper, the adaptive particle swarm optimization model based on multi-objective programming is proposed to solve multinational corporation location problem. Many impact factors that might influence the location of the international company are considered, and we have obtained practical results through our APSO model. In addition, we consider the impact of communications on the location of multinational companies. So, we build the set covering model based on submarine cable distribution to optimize the location of multinational corporations. Our models not only ensure the internationalization of the company, but also save the company resources, and provide an efficient plan to solve company global selection problems.

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