Research on the Location Selection of Agricultural Product Distribution Centers Based on Genetic Algorithm

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Abstract. This paper focuses on the problems of concentrated location selection and high costs of agricultural product distribution centers. Taking Xinjiang as the research object, a location - selection model for agricultural product distribution centers based on the genetic algorithm is constructed. This model comprehensively considers multiple costs such as construction, management, and processing, and simplifies the problem through assumptions. Meanwhile, improved strategies like hybrid coding are adopted to optimize the genetic algorithm for solving the model. A simulation analysis is carried out using MATLAB with a case of a logistics enterprise in Xinjiang. The results show that choosing Ürümqi and Aksu as the locations of distribution centers is the optimal choice, which can reduce the total cost and verify the effectiveness of the model and the algorithm, providing a reference for the location - selection of agricultural product distribution centers.

Keywords: Fresh agricultural products; Site Selection Optimization; Genetic Algorithm.

1 Introduction

The location selection of agricultural product distribution centers is of utmost importance. However, it often encounters problems such as concentrated locations and high costs. These issues can lead to inefficiencies in the agricultural product supply chain, increasing the costs for enterprises and potentially affecting the quality and availability of products. This paper focuses on Xinjiang to tackle these challenges. A location - selection model for agricultural product distribution centers based on the genetic algorithm is constructed. By taking into comprehensive consideration various costs, including construction, management, and processing, this model offers a more comprehensive and accurate solution to the location - selection problem. Meanwhile, strategies like hybrid coding are employed to optimize the genetic algorithm. A case study of a logistics enterprise in Xinjiang is carried out using MATLAB to verify the effectiveness of the modeland the algorithm. The research results can provide valuable references

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for the location selection of agricultural product distribution centers, helping to reduce costs, significantly enhance the overall operational efficiency of the agricultural product logistics industry, and promote the sustainable development of this industry.

2 Location Model Setting and Solution of Distribution Centers Based on Genetic Algorithm.

2.1 Model Setting

When constructing a new agricultural product distribution center model, social-economic factors must be considered to ensure high - quality services at the lowest cost. The model should cover construction, management, processing, sorting, and transportation costs. For the genetic - algorithm - based location - selection model, we make the following assumptions: select from pre-determined sites, one-to-one service rule, meeting all demands, one-time delivery, two-stage road transport, and cost calculation excluding some logistics fees [1].

2.2 Variable Settings

Suppose there are n distribution centers, m agricultural product production sites, and u receiving points. The symbols and explanations of other variables involved in the research are shown in Table 1.

Table 1. Variable setting.

Variable Symbols	Variable Explanation
C	Total cost
C_1	Fixed cost
C_2	Variable cost
R	The land rent of alternative sites for apple cold storage
f	Fixed Cost Coefficient
Q	The capacity of the cold storage built at alternative site i
d_{ij}	The distance from demand point j to cold storage site i
V_{ij}	The driving speed from demand point j to cold storage i
X_i	0 - 1 variable. When $X_i = 0$, it means it is not selected; When $X_i=1$, it means distribution center is selected
Y_{ij}	When $Y_{ij} = 0$, Cold storage i doesn't serve demand point j When $Y_{ij}=1$, it means cold storage i serves demand point j

2.3 Model Construction

Equation (1) represents the fixed cost, which consists of land rent and construction cost. The land rent is related to the number of cold storages built and the fixed rent, while the construction cost of cold storages is related to their capacity and can be calculated as the product of the fixed-cost coefficient of cold storages and their capacity. Equation (2) represents the variable cost, which is related to the actual quantity of fresh agricultural products stored in cold storages. It is mainly used to purchase various production factors to ensure the normal operation of cold storages. Equation (3) shows that the transportation cost is related to factors such as the distance between cold storages and farmers, and can be calculated based on these factors. Equation (4) represents the total cost C in the objective function.

$$C_1 = \sum_{i=1}^{m}(RX_i + fQ) \tag{1}$$

$$C_2 = \sum_{j=1}^{n}\sum_{i=1}^{m}\lambda(Y_{ij}q_j) \tag{2}$$

$$C_3 = \alpha\sum_{j=1}^{n}\sum_{i=1}^{m}d_{ij}Y_{ij}q_j \tag{3}$$

$$C = \sum_{i=1}^{m}(RX_i + fQ) + \sum_{j=1}^{n}\sum_{i=1}^{m}\lambda(Y_{ij}d_j) + \alpha\sum_{j=1}^{n}\sum_{i=1}^{m}d_{ij}Y_{ij}q_j \tag{4}$$

3 Solution Based on Genetic Algorithm

The Genetic Algorithm (GA) originates from large - scale computer - simulated analysis of the evolution of biological systems by humans. Its core lies in constructing an efficient, parallel, and global search space design method [2]. This method can automatically and rapidly collect relevant information during the search process, accumulate knowledge of the search space, and realize the design of an adaptive search process to obtain the optimal solution.

Coding: Representing the problem to be solved with codes is the key to the genetic algorithm. Since a single coding method is difficult to cover all decision - making variables, this study introduces binary coding and real - valued coding. The former is used to represent the decision - making variable, and the latter is used to represent the corresponding transportation share of the decision-making variable. The comprehensive use of these two coding methods can effectively reduce the computational time complexity after genetic algorithm coding and significantly improve the model - solving efficiency [3].

Initial Population Formation: The genetic algorithm is a process of gradual population evolution, and the distribution of the initial population has a significant impact on the overall convergence of the algorithm [4]. Considering the complexity and practicality of the distribution center location - selection problem, this paper uses the rand method to generate the initial population.

Fitness Function Selection: To ensure that the individual genes with specific advantageous traits can be passed on to the next generation, according to the principle of survival of the fittest in biological evolution, a unique and evaluable fitness function needs to be constructed [5]. The optimization problem studied in this paper aims to find the minimum solution of the objective function. Therefore, the following fitness parameters are established:

$$f(x) = \begin{cases} C_x - \alpha & if\ C_x \leq \alpha \\ \frac{1}{C_x - \alpha} & if\ C_x > \alpha \end{cases} \tag{5}$$

4 Example Solution

4.1 Assumptions and Problem Description

A large logistics company in Xinjiang plans to carry out agricultural product processing and distribution business via road transportation. There is a demand for agricultural products in Xinjiang from 10 regions within the autonomous region (Hotan O1, Altay O2, Kashgar O3, Karamay O4, Turpan O5, Changji O6, Ili O7, Tacheng O8, Ürümqi O9, Aksu O10), and there are 5 receiving locations (Jiangsu D1, Fujian D2, Tianjin D3, Guangzhou D4, Beijing D5). The company has 4 candidate distribution centers (Ürümqi T1, Aksu T2, Kashgar T3, Ili T4), and it needs to select 2 - 4 of them to establish distribution centers.

4.2 Example Calculation and Solution

Based on the model set above, this paper uses MATLAB 2020 for processing and calculation. The parameter settings related to the research are shown in Table 2. According to the operation results of MATLAB, Ürümqi City (T1) and Aksu City (T2) are selected as the construction sites of the company's agricultural product distribution centers for the unified storage, processing, sales, and distribution operations of agricultural products. The centralized transportation plan from the agricultural product production sites to the distribution centers solved in this paper is shown in Table 3, and the centralized distribution plan from the distribution centers to the receiving points is shown in Table 4.

Table 2. Genetic Algorithm Parameter Settings

Parameter Settings	Parameter Values
Maximum Iteration Times (Tm)	40
Initial Population Size (N)	200
Crossover Rate (Pc)	0.8
Adaptive Mutation Rate (Pm)	0.1

Table 3. Centralized Transportation Plan from Agricultural Product Production Sites to Distribution Centers

Agricultural Product Production Sites	Concentration Quantity (t)	Distribution Center T1)	Distribution Center (T2)
O_1	7.5	0.24	7.26
O_2	11.4	6.80	4.60
O_3	18.6	10.77	7.83
O_4	19.20	8.90	10.30
O_5	13.80	13.60	0.20
O_6	9.00	0.82	8.18
O_7	12.60	3.60	9.00
O_8	30.00	8.06	21.94
O_9	38.50	38.50	-
O_{10}	30.00	-	30.00

Table 4. Centralized Distribution Plan from Distribution Centers to Receiving Points

Distribution Centers	Maximum Capacity	Receiving Point D1	Receiving Point D2	Receiving Point D3	Receiving Point D4	Receiving Point D5
T_1	108	35.53	23.95	5.72	13.20	29.29
T_2	108	23.04	29.63	36.06	11.29	1.93
Distribution Quantity (t)	-	58.57	53.58	41.78	24.49	31.22

4.3 Result Analysis

The traditional genetic algorithm has problems like premature convergence (early in evolution) and getting stuck in local optima (late in the process). This paper uses hybrid coding in the genetic algorithm. Binary coding and real - valued coding for transportation share cut down computational time complexity. In the same situation, the algorithm needs fewer iterations to reach a good solution. The Cmax in the fitness function changes with generations, making the algorithm search wider and avoid local optima. MATLAB-calculated convergence curves show these improvements work, leading to better results and lower costs. Calculations show building distribution centers in Ürümqi (T1) and Aksu(T2) is optimal.

5 Conclusion

This study deeply explores the location - selection problem of agricultural product distribution centers in Xinjiang Uygur Autonomous Region. By comprehensively considering social - economic factors, a location - selection model aiming at cost minimization is constructed. This model covers multiple costs and has a more complete framework. In view of the defects of traditional genetic algorithms, an enhanced genetic algorithm is introduced. Hybrid coding is used to reduce computational complexity and improve solution efficiency, and the fitness function is optimized to avoid local optima. Through the simulation analysis of a case of a large logistics enterprise in Xinjiang using MATLAB, it is found that choosing Ürümqi (T1) and Aksu (T2) as the locations of distribution centers is the optimal choice, which can reduce the total cost and verify the advantages of the model and the algorithm. Future research can improve the cost - calculation model by incorporating factors such as dynamic market demands and fluctuating transportation costs, and explore the integration of other intelligent algorithms with the genetic algorithm to provide better solutions for the location - selection of agricultural product distribution centers and promote the development of the agricultural product logistics industry in Xinjiang.

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