Optimization and Benefit Assessment of Cold Chain Logistics Network in Southeast Asia Based on Big Data Analysis

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Keywords: Cold Chain Logistics Network Optimization; Benefit Assessment; Big Data Analysis; Ga Algorithm.

Abstract: With the rapid development of social economy, e-commerce and logistics enterprises are flourishing. Continuously improving the optimization and benefit assessment methods of cold chain logistics network has injected new vitality and momentum into the cold chain logistics industry in Southeast Asia. This paper constructs a cold chain logistics network optimization and benefit assessment model in Southeast Asia based on big data technology. At this stage, the development of fresh food e-commerce is very rapid, and the consumption of all kinds of fresh food, dairy products and other perishable commodities is also increasing rapidly, which leads to a huge demand for refrigerated transportation. This is a logistics industry with high entry threshold, large market space and great potential, which is occupied by e-commerce and logistics companies. In this paper, the objective function and constraint function are set as the parameters of GA algorithm calculation through the variables affecting the optimization and benefits of cold chain logistics network, and the optimization model of Southeast Asia's cold chain logistics network based on GA (Genetic Algorithm) algorithm is constructed, and finally, the comparative analysis with the PSO algorithm shows that the computation speed of the GA algorithm is faster than that of the PSO algorithm (the GA algorithm based on the logistics Network Optimization based on GA algorithm has a computation time of only 2.51s, while the model based on PSO algorithm has a computation time of 15s.).

1 INTRODUCTION

The rapid development of agriculture needs the corresponding cold chain logistics system as a guarantee to reduce the loss rate in picking, transportation and storage. Fruit industry and animal husbandry are the pillar industries of its economy, however, there are still many constraints in the development of cold chain logistics of agricultural products, accurate, reasonable and efficient evaluation will directly determine the future development of cold chain logistics of agricultural products. At present, most of the literature on cold chain logistics performance evaluation adopts the fuzzy hierarchical analysis method, because the weights are decided by the decision makers, the evaluation of the decision-making program lacks objectivity. Based on this, this paper discusses the optimization and benefit assessment of cold chain logistics network in Southeast Asia based on GA algorithm, and verifies the feasibility of the model through experiments.

This paper introduces the logistics and transportation network operation cost, GA algorithm and cold chain logistics network optimization model based on GA algorithm in Chapter 3, introduces the experimental comparative analysis of cold chain logistics network optimization model based on GA algorithm and PSO algorithm in Chapter 4, and finally makes a summary of the whole paper.

For logistics network optimization and benefit assessment, there have long been related research proposals by experts. For the longer distribution time in the supply chain, Zhang Y adopts the mixed integer nonlinear programming method to construct a mathematical model and solves it by the discrete continuous optimizer in the general algebraic modeling system. Using the new optimization method, the logistics cost can be effectively reduced and the distribution time can be reduced, thus improving the long-term operational efficiency of the enterprise. Experiments show that the nonlinear logistics distribution center siting problem can be solved effectively with mixed integer nonlinear methods (Zhang et al, 2022).Aloui A studied the

Lin, Y.
Optimization and Benefit Assessment of Cold Chain Logistics Network in Southeast Asia Based on Big Data Analysis.
DOI: 10.5220/0012826200004547

In *Proceedings of the 1st International Conference on Data Science and Engineering (ICDSE 2024)*, pages 497-503
ISBN: 978-989-758-690-3

integrated optimization problem of siting, inventory and path of a two-box-box green logistics network, and established a set of logistics integrated optimization models based on supply chain collaboration and evaluated them. It was found that horizontal collaboration among manufacturers in a supply chain can reduce the overall cost and carbon emissions (Aloui et al, 2022). In order to identify the inefficiencies in the supply chain network.Gupta S considered a fuzzy objective planning based time-cost two-tier decision making process for optimization of product allocation sequence in supply chain network. The results obtained show the optimal quantities to be shipped from different sources to different destinations, which allows managers to discover the optimal quantities of products in a hierarchical decision making process involving two levels (Gupta et al, 2021). Shadkam E proposed a mixed-integer linear programming model with fixed costs, material flow costs, and potential transportation routing costs as objectives. He used the cuckoo algorithm to optimize this model and performed a sensitivity analysis to verify the validity of the model (Shadkam, 2022). Archetti C proposed a method for optimal allocation of goods based on multiple modes of transportation mainly for the combination of modes of transportation. He summarized the existing research results in recent years and pointed out the current research direction and future development direction (Archetti et al, 2022). There are some defects in the current logistics network optimization and benefit assessment models, including that the models are overly dependent on accurate input data resulting in the accuracy of the model output results being affected, and some of the models only focus on the optimization of a single indicator, whereas the actual logistics network involves multiple indicators and multiple stakeholders, and requires comprehensive consideration of multiple factors for decision-making. To address these shortcomings, improvements can be considered in terms of improving the data collection and processing methods of the model, simplifying the model structure, introducing real-time monitoring and feedback mechanisms, strengthening the modelling of uncertainty, and realizing multi-objective optimization.

2 METHODS

2.1 Logistics and Transportation Network Operating Costs

The so-called logistics network is a network structure composed of logistics routes and logistics nodes in logistics activities. The logistics on the route mainly includes trunk transportation and distribution transportation. Logistics at the nodes are mainly packaging, loading and unloading, circulation processing, information processing, distribution, grouping and other activities (Rajput & Singh, 2022, Fontaine et al, 2021). According to the components of logistics activities, the structure of the logistics network can be summarized as consisting of lines performing movement tasks and nodes performing suspension tasks. The network composed of these two basic elements of logistics is the logistics network. In this paper, for the real location situation in Southeast Asia, we not only carry out the design of the location of cold chain logistics center on Southeast Asia, but also include the study of the optimization of the path of the logistics and distribution center on the sales ground (Esmizadeh & Parast, 2021).

The optimization model of logistics and transportation network is an extension of the existing model. For this reason, the model takes the applied research as the core, based on the mathematical and physical model, combined with the basic information data, the optimization planning of the cold chain network cold chain service network is incorporated into the optimization model, so that it can reflect the actual traffic status more clearly (Anderluh et al, 2021). On this basis, the assessment model of cold chain flow is constantly revised and improved on the basis of mathematical statistics and according to relevant specifications. After the initial establishment of the optimal model, various analytical means should also be used to carry out scientific research on it (Tang & Meng, 2021). Firstly, it is necessary to carry out an in-depth study of its technical process to ensure that it matches the actual needs of cold chain logistics; secondly, it is necessary to study its functioning mechanism, so that the established optimization model can essentially guarantee the transportation quality of cold chain logistics. On this basis, the cost analysis of the model is carried out, and on this basis, the cost of each stage is calculated in accordance with the requirements of the optimal model, and the optimal plan is scientifically evaluated on the basis of the cost (Reddy et al, 2022).

Due to the complexity of the logistics and transportation network, which makes the operation of the whole transportation network more and more complicated, each logistics enterprise has not yet formed a perfect cost management system to realize the effective control of the operation cost of the transportation network. Therefore, this paper establishes a standard logistics transportation network operation framework to analyze the operation cost of

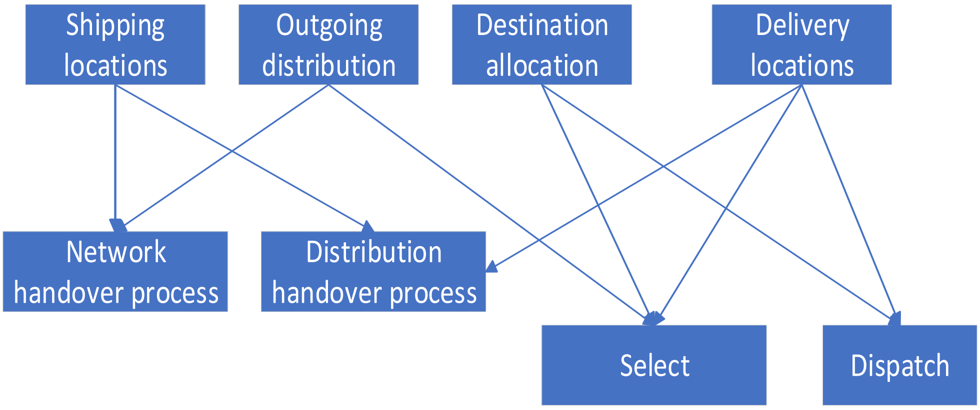

Figure 1: Logistics and Transportation Network Operation Framework (Picture credit: Original).

logistics transportation network, as shown in Figure 1 (Makarova et al, 2021).

As can be seen from Figure 1, the above logistics and transportation network operation framework can effectively complete logistics transportation, because logistics and transportation costs are related to the losses in the transportation, so it can be analyzed by analyzing the various influencing factors in the transportation to determine the logistics and transportation costs.

2.2 GA Algorithm

Genetic algorithm is a stochastic optimization algorithm based on the theory of genetic variation, its idea is simple and easy to implement. The effect is remarkable in practical application. The evolution of animals tends to follow the universal law of "survival of the fittest", that is, those who are best able to adapt to the environment, tend to reproduce more offspring. Genetic algorithms simulate the evolution of organisms under natural conditions, which is a kind of stochastic way to simulate the evolution of organisms (Sohail, 2023).

In genetic algorithms, crossover, mutation is an important generative method, new individuals can enrich the diversity of the population and improve the algorithm's global optimization seeking ability. At the same time, crossover operation is also an important feature that distinguishes genetic algorithm from other algorithms. Crossover and mutation use random generation method, that is, the hybrid individuals and the hybrid position are randomly decided, the selected hybrid individuals are truncated at the intersection point, and then they are interchanged with the corresponding hybrid individuals (Garud et al, 2021). In addition, different individuals can be selected according to different situations, in which the variant position changes from 0 to 1, and the variant that was originally 1 is 0. This method uses a full randomness approach, which gives it strong global optimality seeking ability and enables it to converge to the global optimum (Rostami et al, 2021).

2.3 Cold Chain Logistics Network Optimization Model based on Ga Algorithm

For the two-layer distribution-path optimization planning algorithm constructed in this paper, the optimization objective of the upper-layer model is to select suitable logistics centers from the perspective of logistics center construction cost and distribution of logistics centers, so as to minimize the construction cost of logistics centers. The objective function expression of the upper layer model is as follows.

$$H = \min \sum_{r \in G} C_{pr} d_{pr} Z_r + \sum_{r \in G} F_r Z_r + \theta_1 \sum_{r \in G} (t_{pr} Z_r)^2 \tag{1}$$

$$\sum_{r \in G} Z_r \geq 1 \tag{2}$$

$$\sum_{r \in G} Q_r Z_r \geq \sum_{j \in H} q_j \tag{3}$$

Where $C_{pr} d_{pr} Z_r$ denotes the cost of transporting goods from supplier p to logistics center r, $F_r Z_r$ denotes the construction cost of logistics center r, and $(t_{pr} Z_r)^2$ denotes the loss of goods in the transportation process. The first inequality of the constraints indicates that at least one or more logistics centers must be selected in the transportation network, the second indicates that the amount of goods that can be stored in the logistics center exceeds the retailer's demand, and the third indicates that the logistics center can only be selected or not selected. $Z_r = 1$ denotes a logistics center at r, $Z_r = 1$ denotes no logistics center at r, $r \in G$.

Constraints.

$$\sum_j X_{ij} = 1 \tag{4}$$

$$\sum_k X_{jk} = 1 \tag{5}$$

$$d_{ij} X_{ij} \le D(i,j)_{\max} \tag{6}$$

$$d_{jk} X_{jk} \le D(j,k)_{\max} \tag{7}$$

$$\sum_i q_{ij} \le Q_J^H \tag{8}$$

$$\sum_j q_{jk} \le Z_k Q_k \tag{9}$$

$$\sum_i q_i^S X_{ij} P_j = \sum_k q_{jk} \tag{10}$$

$$q_{jk} \ge 0, q_i^S \le 0 \tag{11}$$

$$P_j \in \{0,2,\cdots,7\}, \forall j \in J \tag{12}$$

$$X_{ij}, X_{ik}, Y_j, Z_k \in \{0,1\}, \forall i \in I, \forall i \in J, \forall k \in K \tag{13}$$

Where, the objective function (1) represents the minimization of the relevant cost,, the$\sum_k 3 \times C_k^L Z_k$ is the leasing cost of leasing fresh produce distribution center per quarter; and$90 \sum_j C_j^H \sum_i q_i^S X_{ij}$ denotes the total processing cost of using pre-cooling station to process fresh produce in each quarter; and $\sum_k Z_k \sum_j Y_j \left[(q_{jk} \frac{90}{P_j}) \times (d_{jk} C_{jk} + C_k^S + C_k^J)\right]$ Indicates that each quarter from the pre-cooling station to the distribution center of the transportation costs and distribution centers within the cold storage, sorting and other operations, the sum of the cost; formula (4) that each product origin only assigned a pre-cooling station for its services; formula (5) that a pre-cooling station and a fresh produce distribution center corresponds to only one; formula (6) that the origin of the product and the pre-cooling station of the transportation distance between the maximum distance limit; formula (7) that the pre-cooling station and the distribution center of fresh produce, the maximum distance limit) indicates that the transportation distance between the pre-cooling station and the fresh produce distribution center satisfies the maximum distance limitation; Eq. (8) indicates that the maximum processing capacity limitation is satisfied in the centralized purchasing cycle of the pre-cooling station; Eq. (9) indicates that the maximum capacity limitation is satisfied within the fresh produce distribution center; Eq.(10) indicates that the inflow and outflow equilibrium is satisfied at the pre-cooling station; Eq. (11) indicates that all the decision variables are positive; and Eq.(12) indicates that The centralized purchasing cycle of fresh produce is maximum 7 days.

The cold chain logistics network optimization problem belongs to the uncertain polynomial problem, and other algorithms have difficulty in solving the global optimum quickly during the solving process.GA algorithm has fast convergence speed and is a global optimization search method, which greatly reduces the solving speed under the same computational accuracy. For this reason, this paper adopts an optimal logistics network optimization method based on genetic algorithm. The current model solving procedure is as follows:

(1) Coding. By the supplier . Manufacturers, distribution centers composed of three-tier logistics network, this paper adopts real number coding, with the vector V to represent the chromosome, $V = (j, m, r, k, i, r, l)$ indicates that the manufacturer to transport mode r from the supplier j to buy. Raw material m to the factory k to produce product i ,and then distributed to the distribution center l by transportation mode r (Palanisamy et al, 2022, Zhang et al, 2022).

(2) Adaptation function. First set the number of suppliers to be selected, the number of factories and the number of distribution centers, this paper will adaptive function is selected as the inverse of the objective function in the model, from the model can be seen, the program with the smallest cost is the optimal chromosome, that is, the adaptive function is the largest (Nikbakht et al, 2021).

(3) Selection. The selection process affects the number of iterations and the speed of convergence,therefore,in the initial selection process,suppliers and distribution centers that are close to the plant are prioritized to be used as parent individuals. The more adaptive the parent individual is, the higher the possibility of crossover and mutation,and it is required that all the individuals with high adaptability should be retained in each offspring community (Vivekanandam, 2021).

(4) Crossover. The crossover operation of genetic algorithms refers to selecting two parent individuals from the parent community with a certain probability and randomly performing structural interchanges on them to generate new offspring individuals (Velliangiri et al, 2021, Mazaideh & Levendovszky, 2021).

(5) Mutation. Mutation in genetic algorithm refers to the selection of different locations of the mother individual, such as suppliers, factories, distribution centers, etc. where random changes occur to produce new individuals. As a general rule, the manufacturer's logistics network is large and extensive. Therefore, in order to reduce the number of iterations and accelerate the convergence, this paper introduces a heuristic algorithm, which divides the suppliers, factories and distribution centers into several regions first, and takes the center of the region as the reference point, and carries out the mutation operation in the direction of the large adaptability, so as to optimize the genetic algorithm improvement.

Individuals in the population are binary coded to represent each initial parameter in the multi-objective ant colony algorithm as well as the site selection parameters of the warehouse. The fitness function is defined according to the two objectives in logistics network optimization, i.e., minimizing the total cost and minimizing the maximum one-way cost, when a certain number of iterations is reached. The algorithm ends, the optimal parameter set is output and used as the initial parameters of the multi-objective algorithm to start solving the Pareto optimal solution set.

3 RESULTS AND DISCUSSION

3.1 Experimental Preparation

Using MATLAB 7.0 Genetic Algorithm Toolbox to run the solution, the average running time was determined by debugging the parameters several times,the average number of running generations to reach the near-optimal solution was 120, and the optimal layout of each node of the cold chain logistics network was finally derived. In this example, Table 1 shows the distances between eight source locations and six alternative cold storage stations. The experiments in this paper do a comparative analysis with the algorithm of this paper through PSO (Particle Swarm Optimization) algorithm.

3.2 Sample Data

Table 1 also shows the average daily deliveries at each source and the maximum daily deliveries at the alternative pre-cooling sites. Table 2 shows the cost per unit of travel from the eight sources to the six alternative pre-cooling sites. The algorithm needs to satisfy the supply demand under the constraints to minimize the total cost associated with the cold chain logistics activities.

Table 1: Distance from the production site to the pre-cooling station and maximum average daily purchases from the pre-cooling station.

The source of a product	I	II	III	IV	V	VI	Maximum supply quantity
1	17	27	49	12	39	71	37
2	38	43	50	78	53	96	76
3	22	43	18	34	29	57	41
4	23	39	88	59	31	105	65
5	324	245	508	115	27	213	73
6	35	155	470	79	51	412	53
7	41	72	66	38	149	81	50
8	106	255	78	95	46	128	80
Maximum Purchase Volume	231	355	510	250	111	250	4910

Table 2 shows the unit distance cost, which is also a key factor in the constraints of the GA algorithm, as a parameter substituted into the GA algorithm.

Table 2: Unit distance cost per unit quality of agricultural products from origin to alternative pre-cooling station (unit: yuan/ton. kilometer)

The source of a product	I	II	III	IV	V	VI
1	7	5	5	8	2	6
2	3	9	3	7	3	6
3	6	5	1	8	10	3
4	7	3	10	3	5	2
5	4	8	7	10	8	9
6	3	6	4	2	2	1
7	6	8	4	8	7	5
8	7	2	3	2	5	3

3.3 Experimental Results

The distribution matrix for the different algorithms is

$$A_{GA} = \begin{pmatrix} 15 & 18 & 47 & 9 & 3 & 20 \\ 31 & 14 & 29 & 44 & 38 & 64 \\ 9 & 35 & 17 & 21 & 13 & 13 \\ 17 & 30 & 49 & 27 & 7 & 7 \\ 84 & 150 & 458 & 86 & 14 & 143 \\ 2 & 69 & 78 & 3 & 21 & 406 \\ 24 & 64 & 25 & 28 & 18 & 61 \\ 47 & 162 & 50 & 71 & 26 & 98 \end{pmatrix} \quad (14)$$

$$A_{PSO} = \begin{pmatrix} 10 & 27 & 3 & 12 & 30 & 38 \\ 5 & 7 & 44 & 78 & 47 & 58 \\ 11 & 9 & 17 & 4 & 15 & 38 \\ 9 & 33 & 49 & 8 & 2 & 9 \\ 114 & 226 & 51 & 0 & 10 & 66 \\ 25 & 78 & 59 & 63 & 42 & 93 \\ 18 & 9 & 33 & 11 & 103 & 62 \\ 70 & 33 & 3 & 33 & 13 & 120 \end{pmatrix} \quad (15)$$

As can be seen from Figure 2, the calculation time of logistics network optimization based on GA algorithm is only 2.51s, while the model calculation time based on PSO algorithm is 15s, so GA algorithm is more able to meet the need of real-time optimization of Southeast Asia's cold chain logistics network. In addition to this the final cost of logistics network construction based on the PSO algorithm is about 23,000,000 yuan, while the cost of logistics network construction of the GA algorithm is about 14,000,000 yuan. So no matter the optimization result or the optimization time of the algorithm to judge, the logistics network optimization model based on GA algorithm is more excellent than the PSO algorithm model. The main reason for this is that GA performs better in dealing with complex, multi-dimensional problems, because it can consider multiple solutions simultaneously and perform global search through gene crossing and mutation operations, which makes it more likely to find the global optimal solution, and compared with PSO, GA usually has better global search and convergence performance, and it can find the optimal solution or close to the optimal solution more quickly.

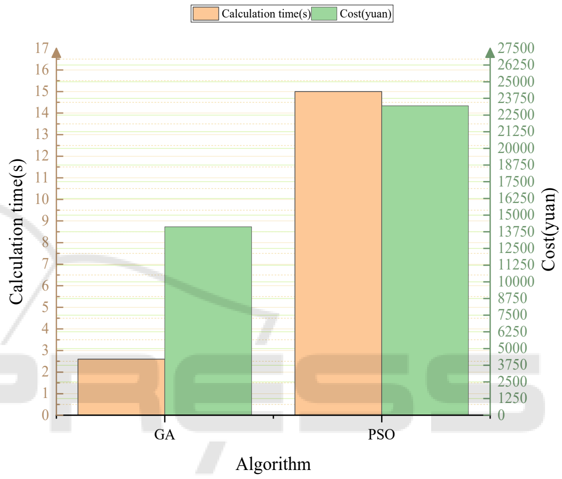

Figure 2: Computation time and cost of results for different algorithms (Picture credit: Original).

3.4 Convergence Speed of Different Algorithms

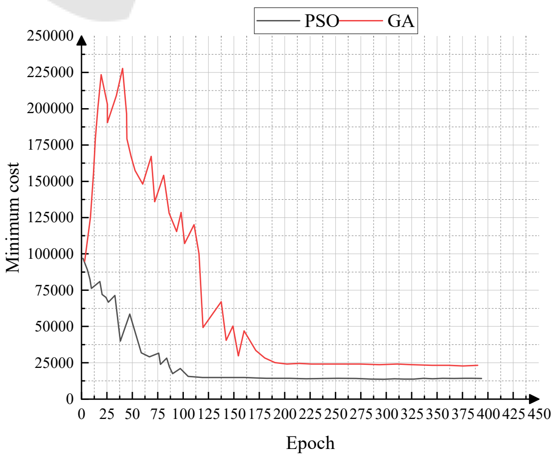

Figure 3: Iteration process of different algorithms (Picture credit: Original).

From Figure 3, it can be seen that the PSO algorithm is close to convergence in 200 iterations, while the GA algorithm has reached the convergence value of minimum cost in only almost 120 iterations. The above data just verifies that the GA algorithm in Fig. 2 is computationally faster than the PSO algorithm. Since the GA algorithm uses crossover and mutation operations to generate new individuals, such operations are able to search the entire solution space faster, thus speeding up the convergence of the algorithm. In addition, GA algorithms are able to process multiple individuals simultaneously in each generation, and therefore are able to perform parallel computations faster, which speeds up the algorithm. In contrast, the PSO algorithm can usually only handle a single individual and therefore will be relatively slow in searching the entire solution space. Therefore, the reason why the GA algorithm is computationally faster than the PSO algorithm is mainly due to its parallel computation and faster search speed.

4 CONCLUSION

With the deepening of globalization, the cold chain logistics industry in Southeast Asia is also attracting increasing attention. Cold chain logistics refers to the logistics method of transporting and storing commodities under constant temperature conditions, which is mainly applied to the transportation of perishable goods such as food, medicine and cosmetics. In Southeast Asia, the development of cold chain logistics faces many challenges due to factors such as hot climate and inconvenient transportation. Therefore, how to optimize the cold chain logistics network and evaluate its benefits through big data analytics has become a pressing issue. The optimization and benefit assessment of cold chain logistics network in Southeast Asia based on big data analysis discussed in this paper is of great significance. Through big data analysis, the operation of cold chain logistics network in Southeast Asia can be better understood and grasped to provide decision support for enterprises and promote the development of cold chain logistics industry. Therefore, the research and application of big data analytics should be strengthened to continuously improve the optimization and benefit assessment methods of cold chain logistics networks, so as to inject new vitality and momentum into the cold chain logistics industry in Southeast Asia.

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