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Research Article

Application of Hierarchical Facility Location-Routing Problem with Optimization of an Underground Logistic System: A Case Study in China

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Facility location problem (FLP) and vehicle routing problem (VRP) are two of the most challenging issues in logistics. This paper presents an exploration of the multinode facility location-routing problem with realistic conditions. The disposal centers, transfer stations, connected collection sites, and unconnected collection sites are built into a new hierarchical model which is solved by Generate Algorithm (GA). Model costs include node construction cost, pipeline construction cost, transport cost, and transfer cost. This paper considers that the transportation is a bidirectional flow not a single flow; each pairs node in the area needs transportation; the dynamic routing selection method is used to determine the routes of unconnected collection sites. FLP and VRP can be both solved in this model. To illustrate the applicability of the model, a case study is presented and the results are discussed. The model in this paper can reduce the cost of the traditional underground logistics system by 6%~8% in experiments.

1. Introduction

The convenience of online consumption has significantly prompted the development of the logistics industry, but the accompanying cost and time concerns had attracted great attention due to the traffic congestion in cities. Accordingly, the future logistics system will gradually shift to the underground, forming an underground logistics system (ULS) [1]. Developed countries such as the Netherlands, the United States, Japan, the United Kingdom, and Germany have initially built ULS. Figure 1 shows the Cargo Cap in Germany.

Logistic companies wish to reduce the overall cost of locating facilities and delivering goods. Instead of solving problems independently and combining their solutions, it is naturally better for such companies to consider problems in an integrated way because decisions can be taken simultaneously benefiting the overall cost minimization. In this sense, the location-routing problem (LRP) can be perfectly suitable for the ULS.

LRP is a combination of two NP-hard optimization problems [2, 3] which are facility location problem (FLP) [4] and vehicle routing problem (VRP) [5]. It is necessary to define, at a minimum cost, where to open facilities (depots, factories, warehouses, etc.) for serving customers' demands in the FLP, while it is necessary to determine routes of an overall minimum cost, which depart from a single facility for serving customers' demands in the VRP. Both objectives must be met, resulting in the overall minimum cost related to locating facilities and determining vehicle routes departing from these facilities to meet customers' demands in the LRP.

FLP has been widely researched. Aikens [6] proposed nine basic location models, including a simple location model, a capacity-limited location model, a demand-changing location model, and a dynamic location model, which were solved by using the Dantzig-Wolfe decomposition algorithm. The subgradient optimization method was used to accelerate the convergence of the above algorithms. Holmberg K [7] considered the location problem of nonlinear transportation costs and solves it by the branch and bound method. Steven J.E. and Russell D.M. [8] also established a location model that considered inventory factors and used heuristic algorithms to solve them. Basti and Sevkli [9] studied p-median FLP aiming to minimize the maximum distance between nodes and facilities. Wang F [10] has

Figure 1: Cargo Cap in Germany.

considered the robust FLP with penalties, aiming to serve only a specified fraction of the clients. Tran T H [11] introduced a large-scale neighborhood search procedure for solving the single-source capacitance FLP (SSCFLP).

Many methods have also been proposed to solve VRP. Clarke and Wright [12] proposed the saving method by listing the savings between points and constructing the path of large to small according to the saving amount. It has the advantage of fast calculation speed, but there are uncombined points and the edge points are difficult to combine. The problem with the scanning method proposed by Gillett and Miller [13] has a good effect, but this is nonprogressive optimization. Vidal T [14] proposed unified hybrid genetic search metaheuristic relied on problem-independent unified local searches, genetic operators, and advanced diversity management methods. Extensive computational experiments demonstrated the remarkable performance of the method which matched or outperformed the current state-of-the-art problem-tailored algorithms. Lai M [15] presented a novel two-stage hybrid metaheuristic method of VRP. The first stage adopts improved ant colony optimization (IACO) to determine the minimum number of used vehicles. The second stage employs improved Tabu search to optimize the total travel cost, in which the initial solutions are obtained by IACO in the first stage.

The studies mentioned above all address either FLP or VRP but not both. For an effective response to an emergency, the planning for these two disaster phases (location and routing) must be coordinated, thus producing an LRP that aims to determine the locations of the depots while simultaneously determining dispatch routes. Location-routing models have been studied by many researchers since the late 1980s. Early LRP was considered in deterministic environments [16–18]. Stochastic location-routing models were subsequently studied by scholars. Toro-Díaz [19] developed a mathematical model for the LRP of emergency medical services with the objective of minimizing the response time and maximizing coverage. Caunhye [20] proposed a two-stage location-routing model with random demands. They solved the model by converting it into a single-stage counterpart. Gao [21] introduced an ant colony algorithm to solve the LRP of dynamic environments consisting of random and cyclic traffic factors. In past years, several other studies on LRP at random environments have been developed, such as Chan [22], Zhu [23], and Marinakis [24].

In this paper, we presented a four-level model (disposal center, transfer station, connected collection sites, and unconnected collection sites) to minimize the cost of the underground logistics system instead of the traditional three-level model (disposal center, transfer station, and collection sites). Meanwhile, the model we proposed can solve FLP and VRP both unlike the currently related research which can only solve them separately.

The paper is further organized as follows. Section 2 presents a brief review of some basic concepts, assumptions, and routing selection method. In Section 3, we formulate a multiobjective optimization model for the determinate phenomenon. Section 4 presented a compared model and the parameter of Generate Algorithm (GA). Section 5 provides experiments and results analysis. Finally, a brief conclusion and outlook for potentially future research are given in Section 6.

2. Preliminaries

This section introduces some fundamental concepts, basic assumptions, and routing selection method.

Based on the existing research, the traditional underground logistics system first divided nodes into three parts which are logistics park nodes (disposal centers), primary nodes (transfer stations), and secondary nodes (collection sites). The logistics park (disposal center) first accepts the goods from the other areas and then transports the goods to the primary nodes (transfer stations) through the underground logistics pipeline after simple selection. The goods are transported through the underground logistics pipeline from primary nodes to secondary nodes (collection sites) after selection and transported to the customer by the secondary nodes. After solving the FLP, some methods are used to calculate the routes [12–15].

In this paper, we first divided nodes into four parts which are logistics park nodes (disposal centers), primary nodes (transfer stations), secondary nodes (connected collection sites), and tertiary nodes (unconnected collection sites). The first two nodes are the same as the traditional underground logistics system, but when goods are transported to secondary nodes (connected collection sites) through underground pipe, they will be transported to tertiary nodes (unconnected collection sites) through ground transport system. After that, the routing will be decided by dynamic path selection method in Section 2.2.

2.1. Assumptions. The model assumptions in this paper:

(1) Each basic node can be transformed into a primary node, secondary node, or a tertiary node, and the amount of freight and distance between each node (the distance considered in this paper is a straight-line distance) are all known.

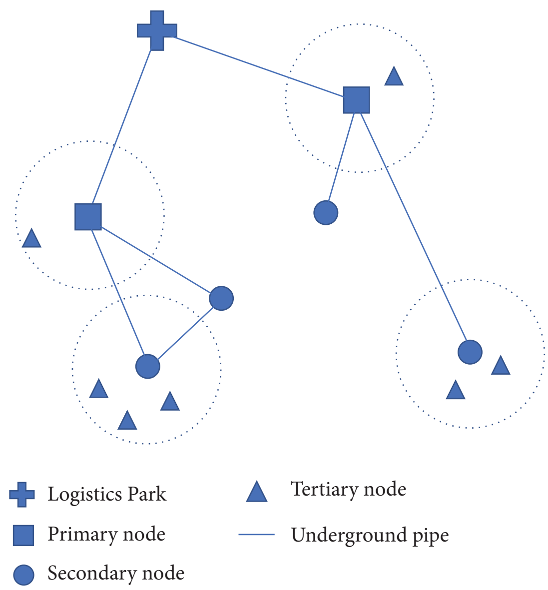

Figure 2: The nodes graph in this paper.

(2) Different primary or secondary nodes have different cargo throughput capacity limits, and those limits are known.

(3) There are no hierarchies of the transport pipelines and the capacity of the pipeline restrictions is known.

(4) The construction costs of the primary and secondary nodes are known. the construction cost of pipeline is related to the length of pipeline regardless of the influence of the terrain or the like.

(5) Transport price of the goods are different from the underground and ground.

(6) The freight volume of two nodes are only allocated to the same transportation pipeline.

(7) The primary nodes and secondary nodes can only serve tertiary nodes within a radius.

(8) Goods within the region can be transported through all nodes.

(9) Price of processing and transshipment of goods for nodes are the same and known.

2.2. Dynamic Routing Selection Method. In the traditional ULS, all nodes are connected to underground pipe which is not necessary. In this paper, we divided secondary nodes into two parts based on whether being connected to underground pipe or not. In this way, we can use the ground transport system and reduce the construction cost of the underground pipelines and nodes; even the ground transportation cost is higher than underground transportation cost because of the waiting cost etc. The logistics underground network in this paper is shown in Figure 2.

In this paper, the route of a tertiary node is not certain because it can use ground transport system with no limit. Therefore, we are using a dynamic routing selection method to decide the route. The reference sample is shown in Figure 3.

As shown in Figure 3, the logistics park node F has cargo to be transported to the tertiary node C. There are two routes selection options:

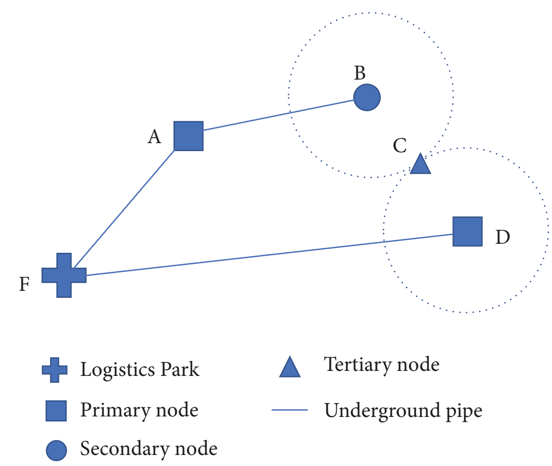

Figure 3: Sample routing selection.

(1) Cargo can be transported from the logistics park F through the underground pipeline FA to the primary node A, then from underground logistics pipeline AB to the secondary node B, and finally by ground to the tertiary node C.

(2) Cargo can be transported from the logistics park F through the underground pipeline FD to the primary node D and then transported by ground to the tertiary node C.

Now, we set the tertiary node C as a secondary node and the underground pipes BC and DC actually exist. Therefore, we can use *dijkstra* algorithm to determine the shortest way of FC; let us call it FDC; and then we can calculate the transport cost of underground routing FC and ground routing DC separately. The determined formula is shown in Section 3.

3. Problem Description

In this paper, the goals of our problem are (1) to determine the subset of nodes and (2) to plan the routes from logistics park to other nodes.

3.1. Notations and Definitions. Let us first introduce the notations and decision variables that will be used to model the problem.

Indices

$i = 1, 2, \cdots, m$: Logistics park

$i = m + 1, \cdots, m + n$: Basic nodes.

Parameters

a_1: Daily depreciation cost for a single primary node

a_2: Daily depreciation cost for a single secondary node

a_3: Daily depreciation cost per kilometer pipeline

a_4: Underground transport cost per ton per kilometer

a_5: Ground transport cost per ton per kilometer

a_6: Cost of transit services per ton of cargo transshipment

r: The serving range

u: The capacity limits of the pipe

v_1: The throughput capacity limits of the primary node

v_2: The throughput capacity limits of the secondary node.

Decision Variables and Decision Vectors

$Q = 1, \cdots, m, m+1, \cdots, m+n$: All nodes set

Q_1: Nodes set of primary nodes

Q_2: Nodes set of secondary nodes

Q_{12}: Nodes set of primary and secondary nodes

Q_{23}: Nodes set of secondary and tertiary nodes

Q_3: Nodes set of tertiary nodes

X: Path existence matrix

x_{ij}: 1 if the pipe between i and j exists, 0 otherwise, $i, j \in Q$

S: Distance matrix

H: Freight volume matrix

D: Available distance existence matrix

$dist(s_{ij})$: The shortest path from i to j through S

w_1: Node construction cost

w_2: Pipeline construction cost

w_3: Transportation cost

w_4: Transfer cost.

3.2. Multiobjective Location-Routing Model. The objective function of this model is the total cost function which includes the node construction cost, the pipeline construction cost, the transport cost of the region, and transfer cost.

3.2.1. Objective 1: Node Construction Cost. According to the path existence matrix X, if a certain node j is connected to a logistics park i, that is, $\sum_i x_{ij} \neq 0, i \in \{1, \cdots, m\}$, $j \in \{m + 1. \cdots, m+n\}$, we can get Q_1 and Q_{23}.

$$\begin{aligned} Q_1 &= \left\{ j \mid \sum_{i=1}^{m} x_{ij} \neq 0,\ j \in m+1, \cdots, m+n \right\} \\ Q_{23} &= \left\{ j \mid \sum_{i=1}^{m} x_{ij} = 0,\ j \in m+1, \cdots, m+n \right\}. \end{aligned} \tag{1}$$

It can be known that a tertiary node is not connected to any other nodes; that is, if $\sum_i x_{ij} \neq 0, i \in Q, j \in Q_{23}$, then the node j is a tertiary node, so we can get Q_3 and Q_2.

$$Q_3 = \left\{ j \mid \sum_i x_{ij} \neq 0,\ i \in Q,\ j \in Q_{23} \right\} \tag{2}$$

$$Q_2 = \{Q_{23} \setminus Q_3\} \tag{3}$$

After the numbers of Q_1, Q_2, and Q_3 are all known, we can calculate the node construction cost using $card(Q)$ which means the number of elements of set Q; that is,

$$w_1 = a_1 * card(Q_1) + a_2 * card(Q_2). \tag{4}$$

3.2.2. Objective 2: Pipeline Construction Cost. According to the available distance existence matrix $D(D = X * S)$ whose element $d_{ij}(d_{ij} = s_{ij} * x_{ij})$ represents the straight-line distance from i to j, we can calculate the pipeline construction cost; that is,

$$w_2 = a_3 * \sum_{i=1}^{m+n} \sum_{j=1}^{m+n} d_{ij}. \tag{5}$$

3.2.3. Objective 3: Transport Cost. The transport cost consists of two parts: one is the transport cost of the node connected to the underground pipeline, and the other is the transport cost of the tertiary nodes.

According to the node distance matrix D, we can determine the shortest distance and the transport order for nodes except Q_3 through $dijkstra$ algorithm. We can calculate the first part of the transportation cost as w_3^0; that is,

$$\begin{aligned} w_3^0 &= a_4 * \sum_i \sum_j h_{ij} \bullet dist(d_{ij}), \\ &\qquad i \in \{Q \setminus Q_3\},\ j \in \{Q \setminus Q_3\}. \end{aligned} \tag{6}$$

According to Section 2.2, for each node i of Q_3, we set the routes whose distance between i and other nodes from Q_{12} is less than the existing serving range. That is, for each i from Q_3, we have node distance matrix L_{ij}^i.

$$l_{ij}^i = \begin{cases} s_{ij}, & s_{ij} \leq r,\ i \in Q_3,\ j \in Q_{12} \\ d_{ij}, & d_{ij} \neq 0 \\ \text{inf}, & d_{ij} = 0 \end{cases} \tag{7}$$

According to the node distance matrix L_{ij}^i, we can determine the shortest distance and transport order for the node i which is from Q_3 through $dijkstra$ algorithm. We set that order as $i \longrightarrow f_1^{ij} \longrightarrow f_2^{ij} \longrightarrow \cdots \longrightarrow f_t^{ij} \longrightarrow j$, so the underground transport distance is $\sum_{i=1}^{t-1} S_{f_i^{ij} f_{i+1}^{ij}} + S_{f_t^{ij} j}$ and the ground transport distance is $S_{if_1^{ij}}$, so we can calculate the second part w_3^1; that is,

$$\begin{aligned} w_3^1 = &\sum_i \sum_j h_{ij} \\ &* \left[a_4 * \left(\sum_{i=1}^{t-1} S_{f_i^{ij} f_{i+1}^{ij}} + S_{f_t^{ij} j} \right) + a_5 * S_{if_1^{ij}} \right], \\ &\qquad i \in \{Q_3\},\ j \in \{Q_{12}\}. \end{aligned} \tag{8}$$

The routing may not be the same because the freight volumes h_{ij} and h_{ji} are not the same. The method we proposed is a dynamic routing selection method, so it is necessary to calculate the transport cost of nodes from Q_{12} to nodes of Q_3. That means that we have another order $j \longrightarrow f_1^{ij} \longrightarrow f_2^{ij} \longrightarrow \cdots \longrightarrow f_t^{ij} \longrightarrow i$, and we can calculate the third part w_3^2; that is,

$$w_3^2 = \sum_i \sum_j h_{ij} * \left[a_4 * \left(\sum_{i=1}^{t-1} S_{f_i^{ij} f_{i+1}^{ij}} + S_{jf_1^{ij}} \right) + a_5 * S_{f_t^{ij} i} \right], \quad i \in \{Q_3\}, \ j \in \{Q_{12}\}. \tag{9}$$

We have calculated the transport cost of nodes from Q_{12} to Q_{12}, Q_{12} to Q_3, Q_3 to Q_{12}, and then we need to calculate the transport cost of nodes from Q_3 to Q_3.

For the node i from Q_3 transport to another node j which is from Q_3, using the dynamic routing selection method; the order should be $i \longrightarrow f_1^{ij} \longrightarrow f_2^{ij} \longrightarrow \cdots \longrightarrow f_t^{ij} \longrightarrow j$, and we can calculate the last part; that is,

$$w_3^3 = \sum_i \sum_j h_{ij} * \left[a_4 * \sum_{i=1}^{t-1} S_{f_i^{ij} f_{i+1}^{ij}} + a_5 * \left(S_{f_t^{ij} j} + S_{if_1^{ij}} \right) \right], \quad i \in \{Q_3\}, \ j \in \{Q_3\} \tag{10}$$

so the total transport cost can be calculated as

$$w_3 = w_3^0 + w_3^1 + w_3^2 + w_3^3. \tag{11}$$

3.2.4. Objective 4: Transfer Cost. According to Section 3.2.3, we have determined all the routing order, so we can get the number of nodes of each routing as p_{ij}, so the transfer cost can be calculated; that is,

$$w_4 = a_6 * \sum_i \sum_j h_{ij} * \left(p_{ij} - 1 \right), \quad i, j \in Q \tag{12}$$

so the objective function of this model is

$$\min w = w_1 + w_2 + w_3 + w_4. \tag{13}$$

3.3. Constraints. (1) The tertiary nodes must be within the service scope of a primary or secondary node; that is,

$$\min_i \left(s_{ij} \right) \le r, \quad i \in Q_3, \ j \in \{Q \setminus Q_3\}. \tag{14}$$

(2) The tertiary nodes are not connected to the underground pipelines; that is,

$$x_{ij} = 0, \quad i \in Q_3, \ j \in Q. \tag{15}$$

(3) All secondary nodes belong to a primary node and form a set with the primary node. The secondary nodes in the set can only be connected to nodes in the set and are not connected to other similar sets of nodes; that is,

$$\sum_j x_{ij} = 1, \quad i \in Q_2, \ j \in Q_1 \tag{16}$$

$$\sum_k \sum_j x_{ij} = 0, \quad k \in Q_1, \ i \in \left\{ j \mid \sum_j x_{kj} = 1 \right\}, \ j \in \{Q_2 \setminus i\}. \tag{17}$$

(4) The cargo flow should be smaller than the pipe capacity limit u; that is,

$$x_{ij} * h_{ij} \le u. \tag{18}$$

(5) The total amount of goods of a secondary node's own goods and the tertiary nodes served shall not exceed the node's throughput capacity limit v_1, v_2,

$$\begin{gathered} \sum_j h_{ij} \le v_1, \quad i \in \{Q_1\}, \ j \in \left\{ j \mid \min_j \left(s_{ij} \right) \le r, \ j \in \{i, Q_3\} \right. \\ \sum_j h_{ij} \le v_2, \quad i \in \{Q_2\}, \ j \in \left\{ j \mid \min_j \left(s_{ij} \right) \le r, \ j \in \{i, Q_3\} \right. \end{gathered} \tag{19}$$

4. Layout Optimization Based on GA

The model established in this paper belongs to the complex space search problem with multiobjective and multiconstraint conditions. The conventional solution method has poor timeliness and large calculation volume. This paper adopts *GA* with migration operation in the heuristic algorithm [25] to solve this kind problem.

4.1. Comparison Model. To verify the validity of this model, we use the model in the literature of YI Mei [26] to conduct a controlled trial. YI Mei uses a traditional optimization model to classify all nodes into primary nodes and secondary nodes. When building the objective function, it not only considers the amount of freight between the logistics park and all nodes, but also considers the amount of freight between nodes.

Since YI Mei's model assumes that the position of primary and secondary nodes are known, we modified YI Mei's model. First, we used *GA* to generate the location of the primary nodes and secondary nodes, and each solution can get an optimal network and the minimum cost through the YI Mei model; then we use the minimum cost as a fitness function to choose the best network and the lowest cost of the issue. The modified model is referred to as a comparison model. For convenience, we call the model of this paper "model *F*" and the comparison model "model *T*".

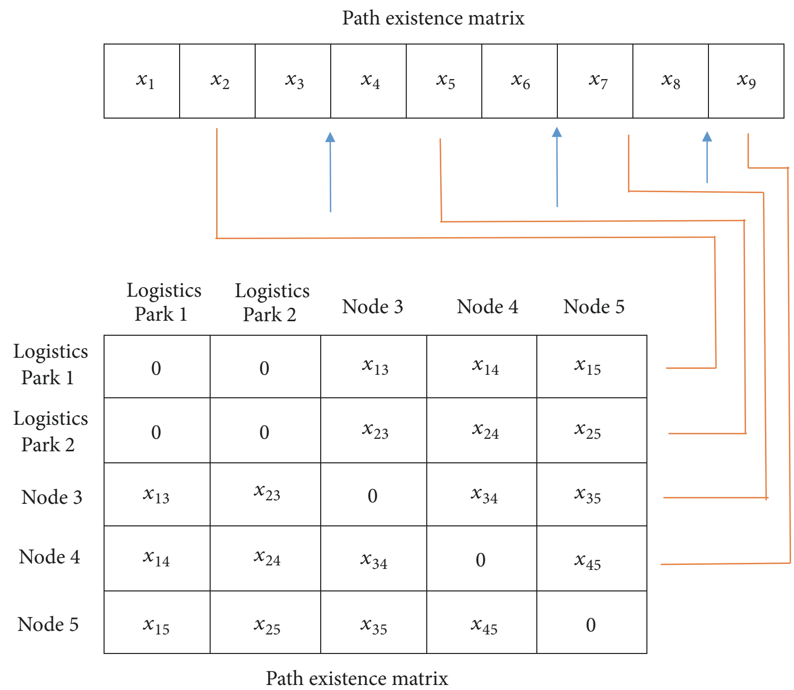

Figure 4: Solution vector and node connection conversion diagram.

4.2. Selecting the Number of Solution Variables. A binary encoding GA is applied for the specific problem of this paper. The solution to the genetic algorithm is a row vector form. The value of each component indicates whether there is an underground pipe connection between corresponding nodes or not. Assume that there are n basic nodes and m logistics parks. Because the logistics parks are not connected with each other and the nodes are not connected by themselves, the pipeline connection corresponding to all components in the solution vector can be converted into an upper triangular matrix with all diagonal elements 0; the solution vector length is $mn + n(n-1)/2$, and the presence matrix is a $(n+m)(n+m)$ square matrix. Assuming there are 2 logistics parks and 3 basic nodes, the solution vector length is 9 and the ordering is represented as $x_1, x_2, \cdots, x_8, x_9$. A 5∗5 presence matrix can be generated from the above variables, as shown in Figure 4.

The first three solutions x_1, x_2, x_3 are converted to x_{13}, x_{14}, x_{15}, which represent the relationship between the path from the 1st logistics park to those three nodes; the solutions x_4, x_5, x_6 are converted to x_{23}, x_{24}, x_{25}, representing the relationship between the path from the 2nd logistics park to those three nodes; and the solutions x_7, x_8 are converted to x_{34}, x_{35}, representing the path existence between the 3rd basic node and the other two basic nodes. The solution x_9 is converted to x_{45}, which represents the existence of a path from the basic node 4 to the basic node 5.

According to the above conversion relationships, the path existence relationship between nodes can be pushed out from the final solution.

4.3. Parameters Setting of GA. The parameters of the GA are shown in Table 1.

Table 1: Parameter settings in the GA.

Number of variables	$mn + n(n-1)/2$
Population type	Double vector
Bounds	0,1
Population size	300
Scaling function	Rank
Selection function	Stochastic uniform
Elite count	20
Crossover fraction	0.8
Mutation function	Constraint dependent
Migration direction	Forward
Migration fraction	0.2
Migration interval	20
Constraint parameters	Augmented Lagrangian
Initial penalty	10
Penalty factor	100

5. Experiment and Result Analysis

The experimental data used in this paper are the data on the 2017 China Graduate Mathematical Contest Modeling Problem F [27]. The logistics data are from Jiangsu Province, China. The competition titles require the construction of an underground logistics network with the lowest total cost.

For better comparing the merits of the models, we randomly select two sets of data from the original data. The first set of data has 2 logistics parks and 20 sets of basic nodes, and the second set of data has 2 logistics parks and 30

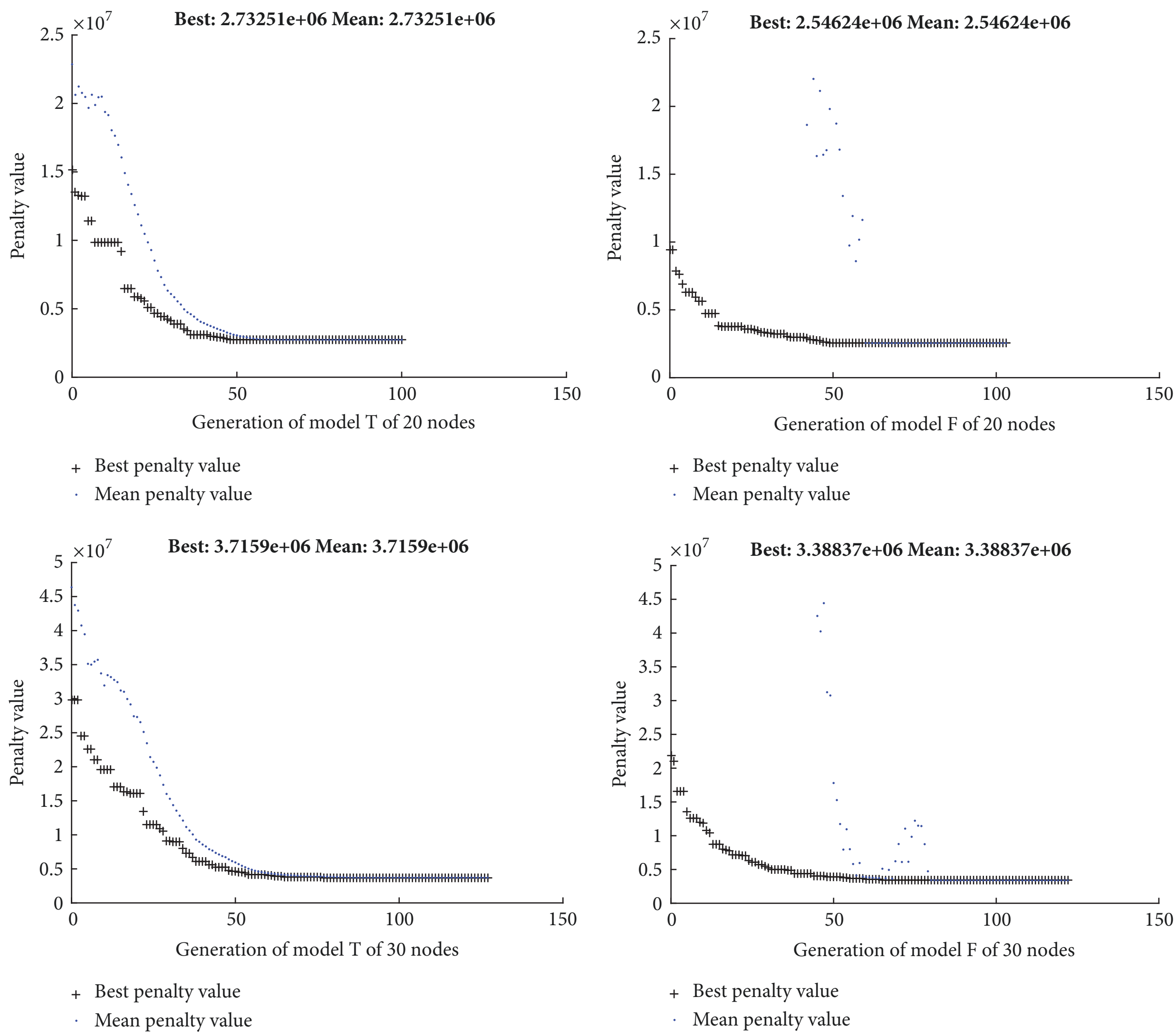

Figure 5: Iterative process of GA of two models.

Table 2: Underground pipeline related expenses.

a_1	4.11 thousand RMB/each node/day
a_2	2.74 thousand RMB/each node/day
a_3	10.96 thousand RMB/kilometer
a_4	1 RMB/ton/kilometer
a_5	2 RMB/ton/kilometer
a_6	1 RMB/ton/time
u	10 ton
v_1	4000 ton
v_2	3000 ton
r	3 kilometers

sets of basic nodes. The relevant costs of nodes and pipeline construction and other parameters are shown in Table 2.

According to the parameters and experimental data, this paper obtains the iterative result graphs and the best individuals for the two models under the corresponding data, as shown in Figure 5.

From Figure 5, we can see that, whether it is a group of 20 basic nodes or 30 basic nodes, the GA can show stable convergence of two different models. Moreover, the total cost of pipe network construction obtained by Model F is less than the total cost of the Model T. With the increase in basic data points, the cost reduction rate is greater. For example, with the 20 basic nodes, the total cost of the Model F is approximately 2.56424 (million RMB/day), while the total cost of the Model T is about 2.73251 (million RMB/day), which is a decrease of 6.16%. Compared to the basic nodes reaching 30 groups, the total cost of Model F is about 3.38837 (million RMB/day), while the total cost of Model T is approximately 3.7159 (million RMB/day), which is a decrease of 8.81%.

Table 3 compares the numbers of the primary, secondary, and tertiary nodes that need to be constructed under the two models. It can be seen that under the Model F, it can be found through the comparison of the number of nodes that, whether in 20 data points or 30 data points, the results

Table 3: Node composition of two algorithms.

	20 nodes		30 nodes	
model	*T*	*F*	*T*	*F*
Primary nodes	5	5	6	6
Secondary nodes	15	9	24	14
Tertiary nodes	0	6	0	14

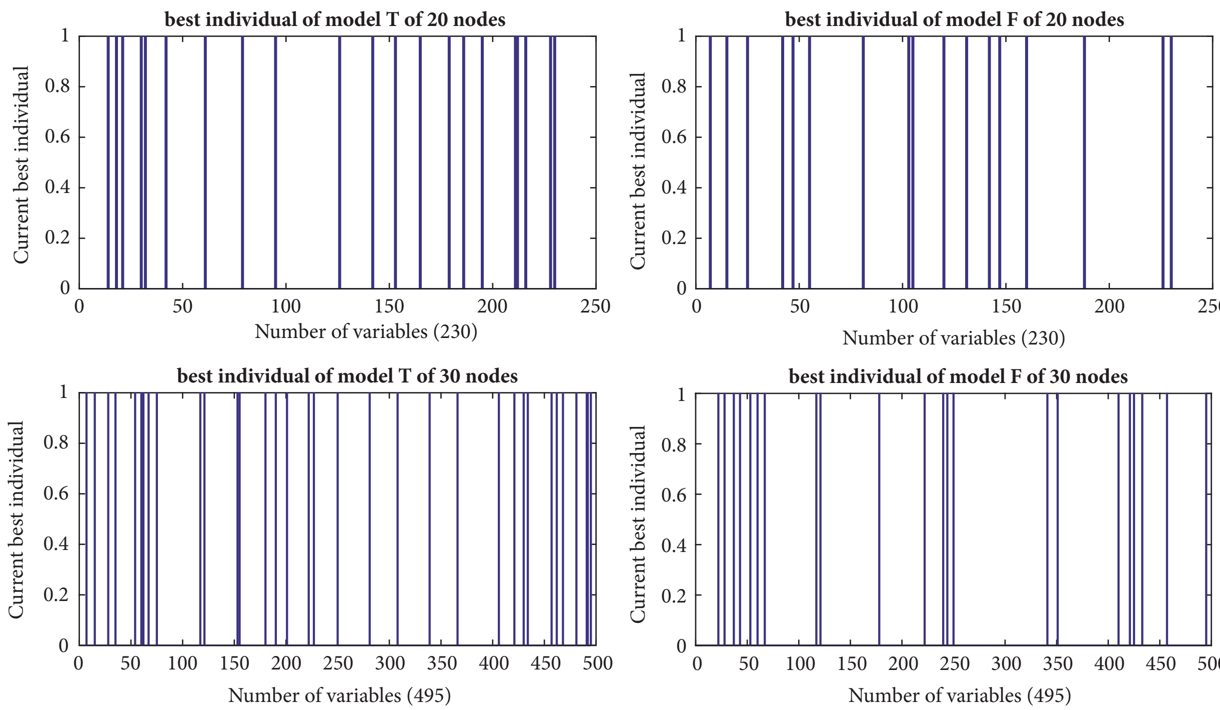

Figure 6: Best individual genetic algorithm in two different models.

obtained by the Model F can greatly reduce the number of nodes to be built in practical applications.

Qualitative Analysis. In the first case, the Model F needs to build 14 nodes in total, and the Model T needs to build 20. In the second case, the Model F needs to build a total of 20 nodes, and the Model T needs to build 30 Nodes which greatly reduce the node's construction costs. Table 4 is a detailed comparison of the total construction cost and the cost of each part of different algorithms. The pipeline construction cost and transport cost of Model F are less than the pipeline construction cost and transport cost of Model T.

Quantitative Analysis. According to the best individual obtained by the GA, specific costs can be obtained as shown in Table 4. From the table, when the node data are 20, the cost of Model F is less than the cost of Model T. This shows that Model F is obviously better than Model T and is implemented.

The best individuals of GA are shown in Figure 6. According to Figure 6, the final underground logistics networks pipeline diagram can be obtained.

Figure 6 indicates all the best individuals corresponding to the solution obtained under two different models of optimization results. According to Section 4.2, these best individuals stand for the corresponding two nodes that need to be connected to an underground pipe. The optimal solution obtained by the genetic algorithm can be converted into a path existence matrix. According to this model, the data on the entire underground logistics network can be obtained. All the best network pipeline diagrams obtained under different models are shown in Figure 7. Model T needs underground pipelines to connect all nodes, but under the Model F, some nodes do not need to connect to underground pipelines under the premise of meeting the distribution scope and can only meet the distribution requirements through the traditional ground logistics transportation.

In Figure 7, the color of the connection between the nodes is given randomly and has no special meaning.

6. Conclusion

In this paper, we studied the multidepot facilities location-routing problem with realistic conditions to build an underground logistics system. This paper considered that the transportation is a bidirectional flow not a single flow, each pairs node in the area needs transport, using the dynamic routing

Table 4: Costs of two models (thousand RMB/day).

	20 basic nodes		30 basic nodes	
Models	*T*	*F*	*T*	*F*
Node build cost	61.6	452.0	90.4	63.0
Pipeline build cost	2165.7	2020.4	2858.7	2705.3
Transport cost	470.6	426.9	710.8	578.0
Transit cost	34.7	28.9	56.0	42.1
Total cost	2732.5	2546.2	3715.9	3388.4

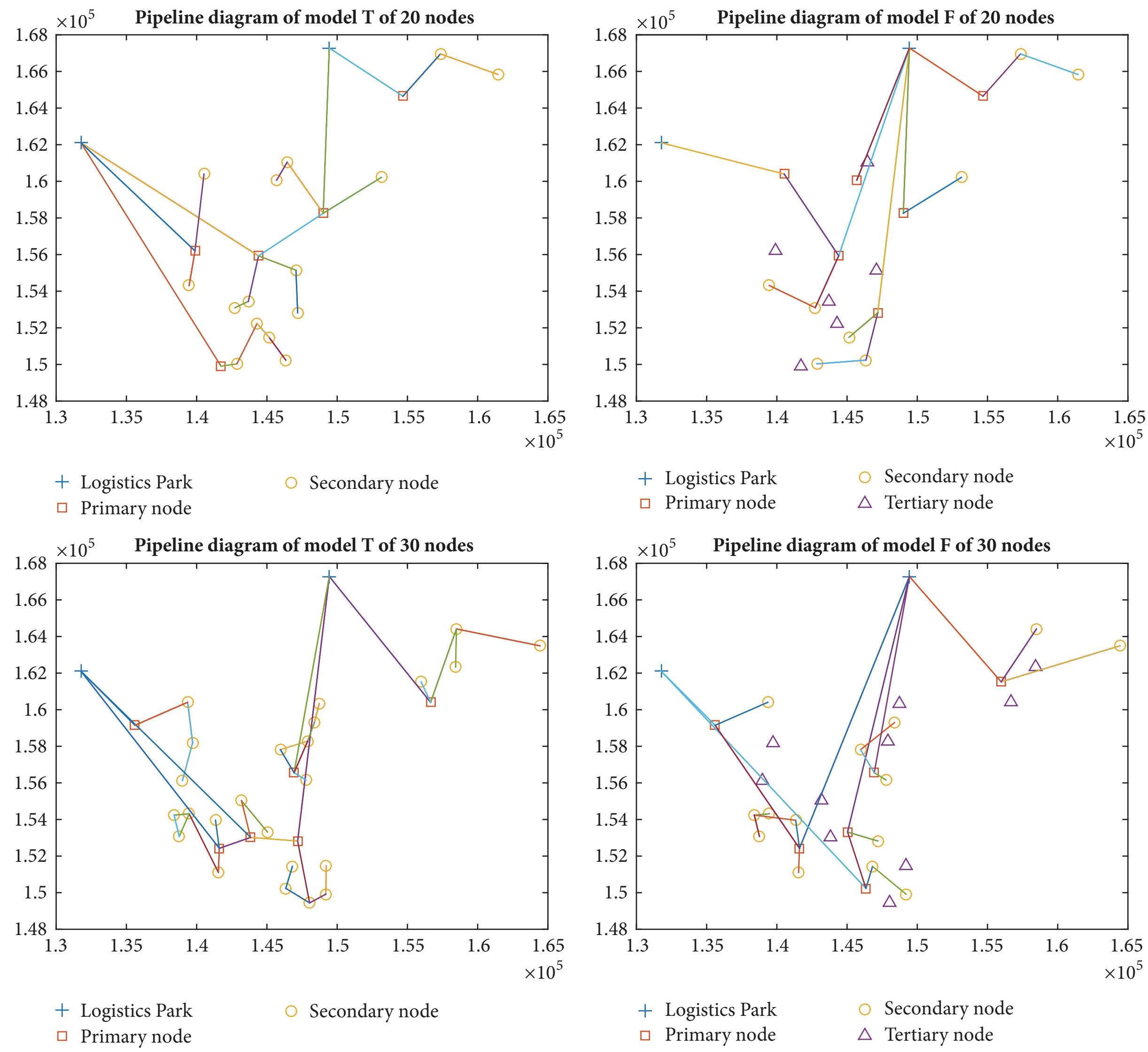

Figure 7: Pipeline diagrams of two models under different sets of data.

selection method to determine the routing of unconnected collection sites. Due to the computational complexity of the model, a genetic algorithm was designed to solve the proposed model. The efficiency of the proposed model was illustrated with experiments. Compared with previous work, the main contribution of our paper is to propose a new four-level hierarchical model which simultaneously considered the FLP and VRP both.

Data Availability

The total data we use in the paper is owned by a third party. It can be checked from the following link: http://gmcm.seu.edu.cn/01/49/c12a329/page.htm This data is used to support the China Postgraduate Mathematical Contest in Modeling. We did not use all the data. To better compare the advantages and disadvantages of our established models and traditional models, we randomly selected two sets of data of different sizes from all the data used to conduct experiments. If you need these data sets, we can submit them to you. They are also available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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