Analysis and Optimization of Operational Process of Pharmaceutical Logistics Distribution Center Technical Report

0 Abstract

This design is mainly based on the above-mentioned Yaobei Investment Co., Ltd., and two of the 67 distribution centers owned by Beijing are selected to be converted into medical warehouses. The methods used are clustering and ant colony-based routing algorithms; according to the actual EIQ information The internal facilities of the pharmaceutical logistics distribution center are planned, and its facilities include shelves, ground stacks and recheck packing stations; the 2057 orders of the pharmaceutical logistics distribution center are assembled into 62 grouping orders, and the mileage saving algorithm is used to achieve this; in the process of picking In the paper, the ant colony algorithm is used to optimize the picking order of 62 sets of orders, and finally the simulation software is used to establish a 1:1 simulation model to verify the algorithm, so that it can save the walking distance of the pickers; the delivery process proposes two The two distribution schemes are compared in the dimensions of the shortest path and the urgency of medicines. The traveling salesman algorithm is used to draw conclusions. Finally, simulation software is used to simulate the two schemes, and the scheme with the least freight is selected.

Keywords: Pharmaceutical Distribution center, Location Selection, Facility Planning, Picking Strategy Optimization, Distribution Route Optimization

1 Planning and analysis of the construction process of the pharmaceutical logistics distribution center

1.1 Subject background and significance

The status of pharmaceutical logistics in China has gradually improved. Therefore, Shanghai Pharmaceutical North Investment Co., Ltd. selected two of the 67 distribution centers in Beijing with more suitable geographical locations to become drug warehouses, and then planned its internal facilities, and the planning was based on applicable Based on the principle of medicine; in the picking strategy, the mileage-saving algorithm is used to organize the order into a grouping list, and the ant colony algorithm is used to optimize the picking order, in order to change the past S-shaped picking order to U-shaped picking order , To avoid repeated routes for pickers; use the traveling salesman algorithm to plan two distribution routes with the shortest path and the urgency of medicines in the distribution process, and compare them, and select the best solution with less distribution freight.

The above design can increase the development of medical logistics and rationally plan the facilities of the medical logistics distribution center. In the picking strategy, the optimization of the algorithm is used to avoid the pickers from repeating the road, which effectively reduces the walking distance of the pickers, and in the delivery process With the two plans in the plan, you can intuitively see the delivery freight of the two plans, and select the best plan, which greatly reduces the cost of delivery.

1.2 Process analysis and design of medical logistics distribution center

The design is based on the actual needs of Shanghai Pharmaceutical North Investment Co., Ltd., and analyzes the process of the pharmaceutical logistics distribution center. It is divided into four modules, namely distribution center location, picking strategy analysis, distribution process analysis, and distribution center facility planning.

1.3 Location Planning of Pharmaceutical Logistics Distribution Center

1.3.1 Site selection method

Find the geographic coordinate location of the hospital based on the existing 2047 order distribution, divide the hospital's coordinates into several clusters (not reflected in the results) according to the requirements for the optimal output of the program, and select the location from the several clusters The two distribution centers in need, because the location planning is a structured design oriented to the overall process, rather than oriented to a single result, the C++ language is used for compilation.

The location selection problem of multiple distribution centers in the logistics system is essentially a multi-objective optimization problem. It is difficult to determine the similarity function between the various types by simply using the cluster-based ant colony algorithm. Therefore, the selection based on the clustering The algorithm of class and ant colony path finding is used for site selection.

1.3.2 Technical feasibility analysis

The basic idea based on clustering and ant colony routing algorithm is to regard the location of the distribution center as a clustering problem, compare the ants in the algorithm to a truck, compare the cell to a distribution center, and treat multiple candidate distribution centers as clustering centers , Each distribution point is regarded as the quantity to be classified, and the goal is to use multiple ants to assign each distribution point to the distribution center based on the lowest system cost of the distribution center location model to form multiple cells. If the distribution center is used as a cluster If the cell cavity in the center is not empty (that is, the cell cavity contains a distribution point), then the distribution center is retained; if the cell cavity is empty (that is, the cell cavity does not contain a distribution point), the distribution center is redundant and is removed. To determine the address and quantity of the distribution center. Therefore, the multi-distribution center location algorithm based on the clustering idea combined with the ant colony path optimization algorithm has technical feasibility.

1.4 Facility Planning of Pharmaceutical Logistics Distribution Center

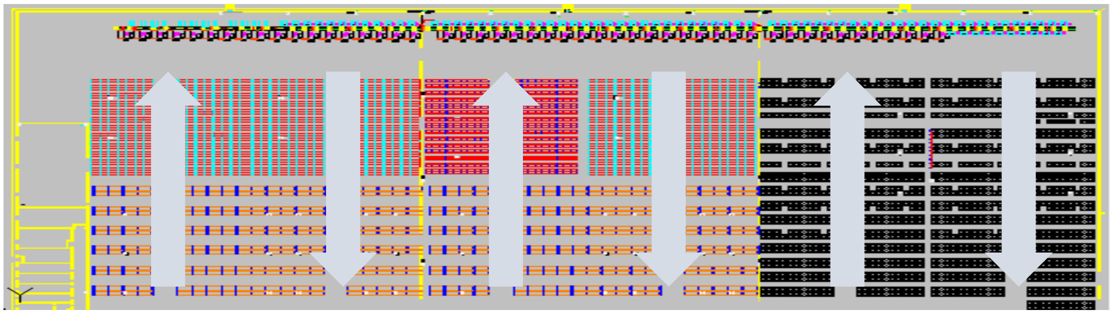
After the distribution center is selected, the facilities of the distribution center should be planned. Here, the basic data of EIQ, the basic information of the shelf and the basic information of the rechecking packing station are needed to calculate the number of shelves and the single and multi-piece checking packing stations. The use of SLP for the distribution of various facilities should also be determined according to the goals of the facility layout. While the requirements of the composite process, the space should be used most effectively, and the cost of material handling should be minimized.

1.5 Picking Strategy Planning of Pharmaceutical Logistics Distribution Center

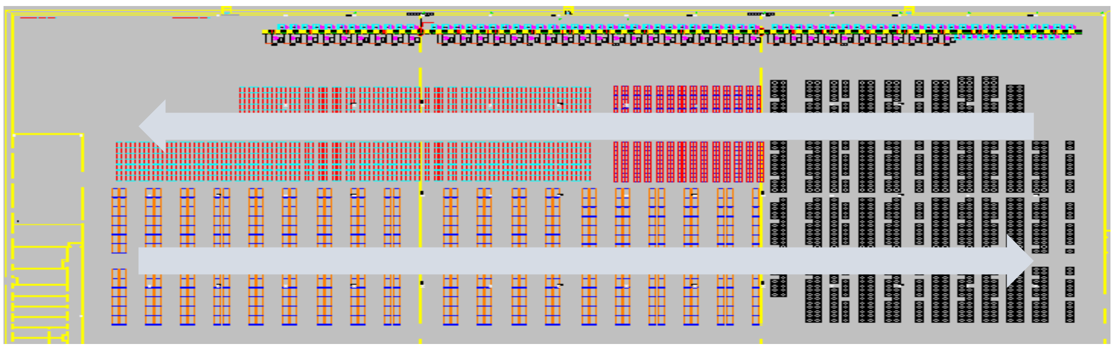
1.5.1 Analysis of Picking Strategy

In the warehouse of the pharmaceutical logistics distribution center, the path optimization of the drug sorting step is worthy of research. Because the automated mode of drug receiving, putting on shelves, and sorting is more and more commonly used in warehouses, the optimization of manual picking strategies has become more and more important.

After business research, the warehouse area of a pharmaceutical company is currently planning the picking path in a way perpendicular to the picking area. The S-shaped path of the warehouse pickers can only be avoided when picking from the two ends of the shelf. Do not go back, this kind of picking strategy is relatively limited, the S-type picking strategy is shown in the figure.



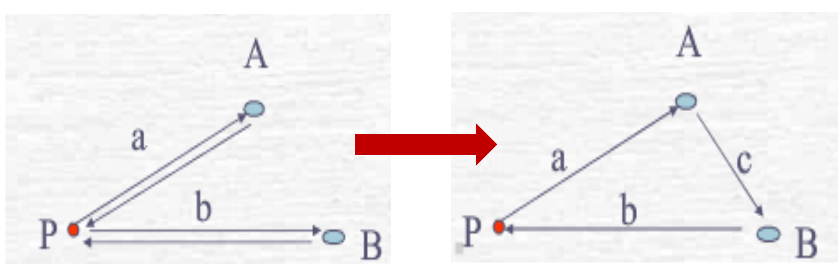
In the design, it was found that a more optimized picking strategy is to walk on a U-shaped path, so that any packing station can be used as a starting point, so that repeated walking can be effectively avoided by making a circle, as shown in the figure.



As shown in the figure above, in order to ensure that the order tasks assigned to the packing station are balanced, the pickers deliver each review station basically evenly distributed. After the picker has cast to the leftmost review station, when the picker selects the next task according to the order, he needs to go to the far right to start picking. If the picking sequence can be effectively shortened from the left of the picking area at this time The walking distance of the picker.

1.5.2 Planning of collective order formation

In this design, the main target is the combination of large orders for hospitals. The orders with a relatively close storage position are grouped into a set of grouping orders, so that the pickers can pick the goods, which can effectively reduce the walking path and save money. In a broad sense, the mileage algorithm refers to the most famous heuristic algorithm used to solve the problem of the number of transportation vehicles. Therefore, the mileage saving algorithm is used in this design. The model of the mileage saving algorithm is shown in the figure.



For example: Take P as the initial point, and go to the A and B storage points respectively, then the mileage saved is

$$2 * (a+b) - (a+c+b) = a+b-c$$

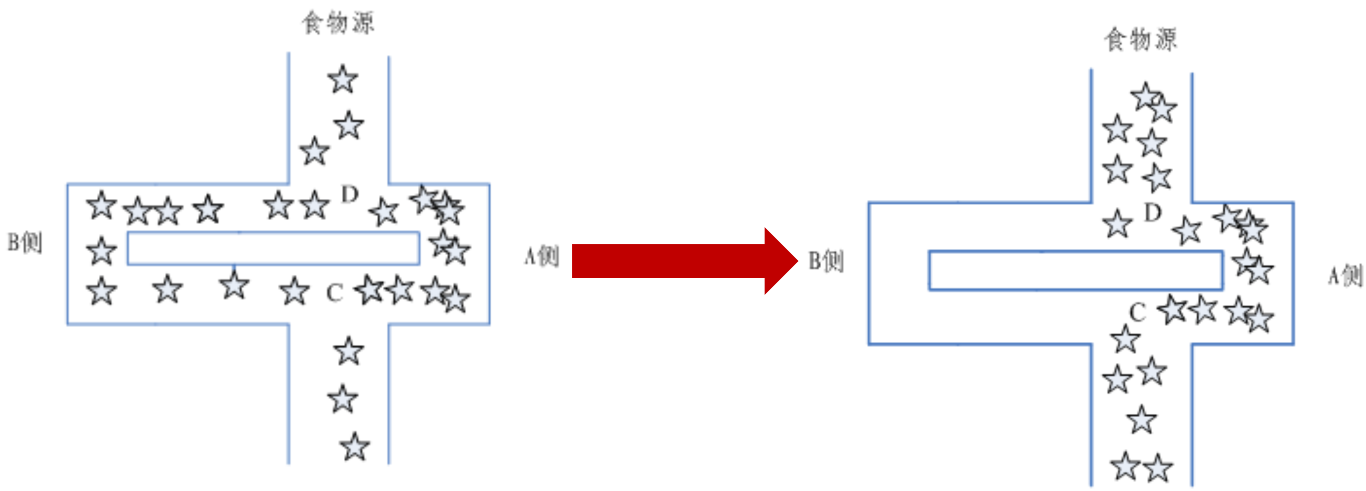
Here, the basic idea of the mileage saving algorithm is as follows: select the order with the largest travel distance as the initial order, and then calculate the mileage saved after combining other orders with the initial order and add the order with the largest mileage to the original order and generate a new one. The initial order, and then the loop continues until you get less than or equal to 20 orders as a collective order.

1.5.3 Picking sequence planning

Since the past S-shaped picking order is changed to U-shaped picking order, two algorithms are proposed for picking paths, ant colony algorithm and greedy algorithm (greedy algorithm). In order to select a suitable algorithm, In the following analysis, the comparative analysis of the two algorithms is shown in the table.

Ant Colony Algorithm	**Greedy Algorithm**
Approximate Algorithm	Determine the algorithm
Overall optimal solution, global optimization	Local optimal solution, step-by-step optimization
Considering the whole, and constantly looking for the best path	Only doing it is the best option at the moment
After-effect, the states can influence each other	No aftereffect, the process before a certain state cannot affect the subsequent state
High efficiency for complex models	Higher efficiency for simple models

Since the warehouse designed this time has a lot of shelves and the model is more complex, the most important thing is that we need to optimize the overall situation in this sorting strategy. We need to optimize the shortest path at the same time as the grouping and single strategy. The algorithm runs when the two are connected, so the ant colony algorithm is finally chosen to optimize the picking order. The ant colony algorithm model is shown in the figure.



As shown in the figure, when countless ants return from the food source to the ant colony, they will release pheromone on the road. However, because the distance between the ants passing side A is short and the accumulated pheromone is much, subsequent ants will tend to move along the route with more pheromone. , To achieve the shortest distance effect.

1.5.4 FlexSim simulation model planning

FlexSim is an object-oriented simulation environment system, which has a high degree of simulation reduction for logistics enterprises. In this simulation software, not only can the drawings drawn by Auto CAD be imported, but also fixed flow node modules can be directly added. The walking path of the picker is generated immediately, and the simulation effect is excellent.

Therefore, in order to verify the feasibility of the mileage saving algorithm of the group collection single strategy and the ant colony algorithm for the optimization of the picking order, the FlexSim simulation software is used to simulate the drug warehouse at a ratio of 1:1. The main purpose is to use the old collection. Simulate and compare orders and new collection orders with the old and new algorithms to get the final picking path.

1.6 Distribution route planning of medical logistics distribution center

1.6.1 Distribution route plan planning

Certain route planning must be carried out for the distribution of medicines. In order to better complete the delivery task, we must optimize the path of each truck and its load in different pharmaceutical companies, and arrange the delivery routes of the vehicles correctly and reasonably, so as to achieve the overall optimization goal of reducing transportation and delay costs. .

The path planning belongs to the traveling salesman problem (TSP Problem) in the non-deterministic polynomial (NP) complete problem. The Dijkstra algorithm is required to solve the optimal path. The optimal path can be selected through the shortest path and the urgency of medicines. , So choose the traveling salesman problem as the algorithm of distribution route planning.

1.6.2 Technical feasibility analysis

The Traveling Salesman Problem (TSP) is a non-deterministic problem of polynomial complexity. It is mainly used to solve how each traveling salesman plans a route containing multiple nodes to make the total path the shortest. In the logistics and distribution process, the traveling salesman (truck) has changed from one to multiple. A certain number of customers are the nodes in the TSP problem. The distribution center needs to plan an appropriate path for each truck. Under certain constraints, To achieve such goals as the smallest distance, the smallest time, and the smallest cost. Therefore, the traveling salesman problem is suitable for the planning of the distribution process and has technical feasibility.

1.6.3 Simulation model analysis

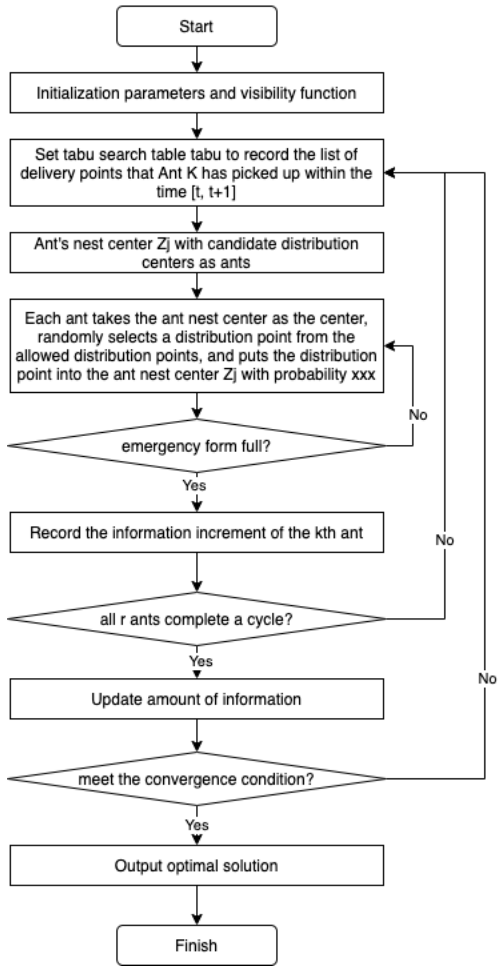
We first use the TSP algorithm to initially plan the optimal route from the distribution center to the 26 hospitals. In order to prove the feasibility of the algorithm, we also need to establish a simulation model to verify the feasibility of the algorithm.

We found that AnyLogic software can add the actual map of Beijing to the software, add GIS information, and simulate the transportation plan we designed, and it can also consider factors such as transportation cost and time. In route planning, it is not Based on the distance between the two points of the physical location, it is calculated by the actual road network data, the route of the vehicle is intuitively represented by animation, and the delivery freight is calculated at the same time, which can provide decision-making data for the actual transportation we carry out. To achieve the purpose of improving distribution efficiency and reducing distribution costs.

2 Location Design of Pharmaceutical Logistics Distribution Center

2.1 Process of path finding algorithm based on clustering and ant colony

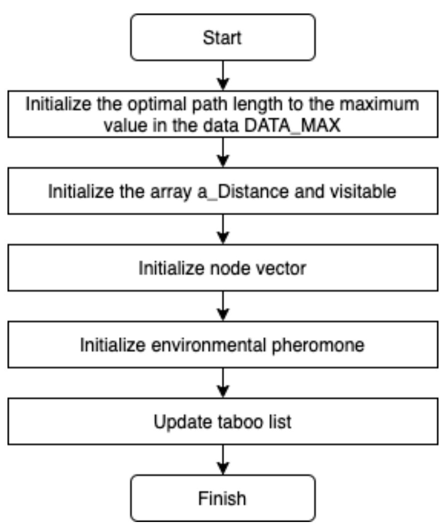
First, initialize the parameters and the visibility function in the beginning process, set the taboo search table, and then record the list of distribution points that the ants have walked in a certain period of time, center each ant on the nest center, and randomly among the allowed distribution points Select a delivery point and put the changed delivery point in the ant nest center. If the emergency list is full, record the ant's information increment, otherwise repeat it into the ant nest center, and update the information when all ants have completed a cycle When the convergence condition is met, the optimal solution is output. For this process design, see the figure.



2.2 Core function programming

2.2.1 Initialize data

Before selecting the distribution center, the data must be initialized. The program flow chart of this function is shown in the figure.

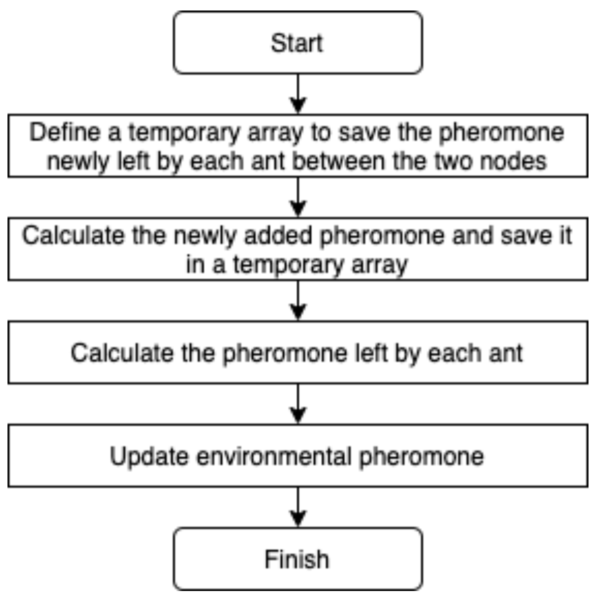


In the process of initializing data, initialize the optimal path length to the maximum value in the data, then initialize the arrays a_Distance and visitable, then initialize the node vector and environmental pheromone, and finally update the taboo table. The core algorithm of this function is shown in the figure.

```
m_BestAnt.m_dataPathLength = DATA_MAX;
  ADD_NODE_COUNT = num_node;                                              //计算两两节点间距离
  for (int i = 0; i < ADD_NODE_COUNT; i++) {
    for (int j = 0; j < ADD_NODE_COUNT; j++) {
      a_Distance[i][j] = DATA_MAX;                                        //初始化数组a_Distance和visitable
      visitable[i][j] = true;                                             //使用visitable数组记录某个节点是否可访问
    }
  }
  EdgeList::iterator change_it;
  for (int i = 0; i < num_node; i++) {                                    //初始化节点向量
    for (change_it = change_vec[i].begin(); change_it != change_vec[i].end(); change_it++) {
      a_Distance[i][change_it->to] = MIN(change_it->cost, a_Distance[i][change_it->to]);
    }
  }
  for (int i = 0; i < ADD_NODE_COUNT; i++) {                              //初始化环境信息素
    for (int j = 0; j < ADD_NODE_COUNT; j++) {
      a_Trial[i][j] = 2.0;                                                //在起始，先将节点间的信息素设置为相同的2.0
    }
  }
  UpdateAvoidPath(list, a_Trial);                                         //更新禁忌表
```

2.2.2 Update environmental pheromone

The environmental pheromone needs to be updated every time a new location is selected. The program flow chart of this function is shown in the figure.

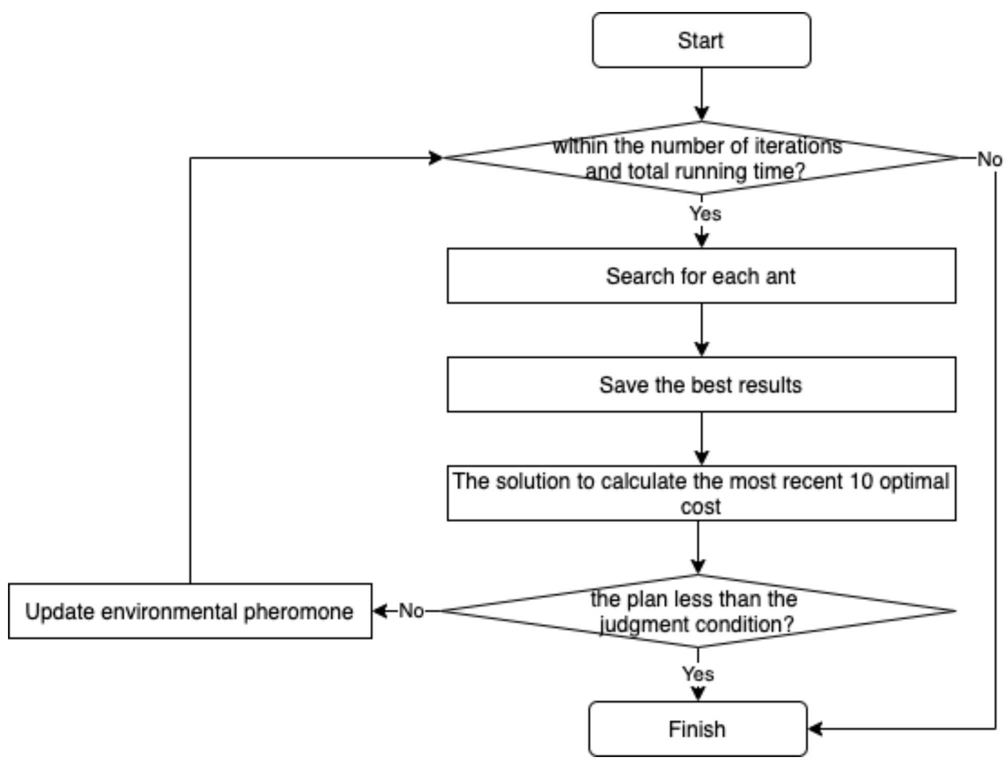


In the code to update the environmental pheromone, first define a temporary array to save the pheromone newly left by each ant between the two nodes, and then calculate the newly added pheromone and save it in the temporary array and calculate the left by each ant After the pheromone updates the environmental pheromone, the core code is shown in the figure.

```
double **dataTempAry = (double **) malloc(sizeof(double *) * ADD_NODE_COUNT);    //临时数组，保存各只蚂蚁在两两节点间新留下的信息素
for (int i = 0; i < ADD_NODE_COUNT; i++)
    dataTempAry[i]   = (double *) malloc(sizeof(double) * ADD_NODE_COUNT);
for (int i = 0; i < ADD_NODE_COUNT; i++)
    for (int j = 0; j < ADD_NODE_COUNT; j++)
        dataTempAry[i][j] = 0;    //计算新增加的信息素，保存到临时数组里
int m = 0;
int n = 0;
for (int i = 0; i < ADD_ANT_COUNT; i++) {    //计算每只蚂蚁留下的信息素
    for (int j = 1; j < m_cAntAry[i].m_nMovedNodeCount; j++) {
        m = m_cAntAry[i].m_nPath[j];
        n = m_cAntAry[i].m_nPath[j - 1];
        dataTempAry[n][m] = dataTempAry[n][m] + DATAQ / m_cAntAry[i].m_dataPathLength;    //节点n->节点m的信息素
    }
}
for (int i = 0; i < ADD_NODE_COUNT; i++) {    //更新环境信息素
    for (int j = 0; j < ADD_NODE_COUNT; j++) {
        g_Trial[i][j] = g_Trial[i][j] * ROU + dataTempAry[i][j];    //最新的环境信息素 = 留存的信息素 + 新留下的信息素
    }
}
for (int i = 0; i < ADD_NODE_COUNT; i++)
    free(dataTempAry[i]);
free(dataTempAry);
```

2.2.3 Find the optimal path

In the process of site selection, two more suitable distribution centers should be selected according to the shortest path principle. The program flow chart of this function is shown in the figure.



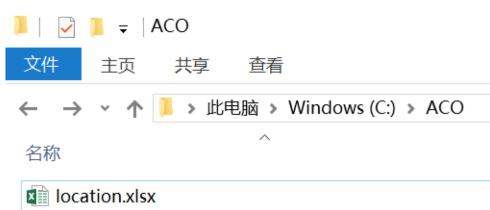
In the code to find the path, if the number of iterations and the total running time, each ant will be searched and the best result will be saved, and then the tea will be searched if the variance is less than the judgment condition. The path is successful, otherwise the iteration and running time calculation will be performed again. The core code of this function is shown in the figure.

```
    clock_t end_time;
    int passCount = (int)demand.pass.size();
    passCount = MIN(passCount, 20);
    passCount = MAX(passCount, 1);
    double * cost_temp = (double *)malloc(size_t(sizeof(double) * passCount));
    for(int  i = 0; i < passCount; i++) cost_temp[i] = DB_MAX;          // 在迭代次数和总运行时间内进行循环
    for (int i = 0; i < N_IT_COUNT; i++)
    {
        int dead_ants = 0;                                              // 死掉的蚂蚁数量
        for (int j = 0; j < N_ANT_COUNT; j++)                           // 每只蚂蚁搜索一遍
        {
            m_cAntAry[j].Search(demand, g_Distance, g_Trial);
            if (m_cAntAry[j].m_dbPathLength == DB_MAX)
                dead_ants++;
        }                                                               // 保存最佳结果
        for (int j = 0; j < N_ANT_COUNT; j++)
        {
            if (m_cAntAry[j].m_dbPathLength < m_cBestAnt.m_dbPathLength)
            {
                m_cBestAnt = m_cAntAry[j];
            }
        }
        cost_temp[i % passCount] = m_cBestAnt.m_dbPathLength;           // 计算最近10次最优代价的方差
        double average = 0, s2 = 0;
        for(int k = 0; k < passCount; k++) average += cost_temp[k];
        average /= passCount;
        for(int k = 0; k < passCount; k++) s2 += (cost_temp[k] - average) * (cost_temp[k] - average);
        if(s2 <= CONVERGENCE && cost_temp[0] != DB_MAX) break;          // 如果方差小于判定条件，那么收敛，退出循环
#ifdef _LOCAL_DEBUG
        std::cout << "Gen: " << i << "average: " << average << " s2: " << s2 << endl;
        for(int k = 0; k < 10; k++) std::cout << cost_temp[k] << " ";
        std::cout << endl;
#endif                                                                  // 更新环境信息素
        UpdateTrial(g_Trial);                                           // 如果时间用完，也退出搜索
        end_time = clock();
        if (double(end_time - start_time) / CLOCKS_PER_SEC > time)
            break;
    }
#ifdef _LOCAL_DEBUG
    std::cout << "time: " << time << endl;
#endif
}
```

2.3 Input and output results

(1) Input file location.xlsx

First enter the names and latitudes and longitudes of all pharmacies into the Excel table. Store the Excel file in the "C:/ACO/" path, as shown in the figure.

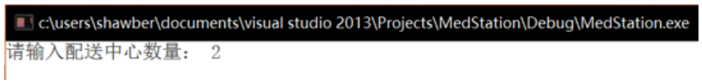


(2) Import storage code data: the program will read the contents of the "order.xlsx" file from "C:/Order/" by default, as shown in the figure.

location.xlsx - Excel

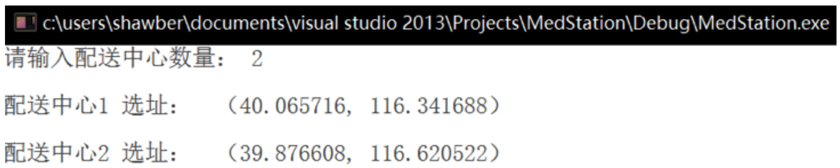
	A	B	C
1	名称	纬度	精度
2	首都医科大学附属北京天坛医院	39.882689	116.410207
3	宣武医院	39.89866	116.369696
4	中国人民解放军总医院	39.911723	116.283236
5	空军总医院	39.927833	116.307809
6	中日友好医院	39.980342	116.43262
7	协和医院(东院)	39.918626	116.423937
8	解放军第307医院	39.867371	116.300875
9	北京中医院	39.938089	116.414588
10	中国人民解放军第二炮兵总医院	39.962958	116.378077
11	首都医科大学附属北京安贞医院	39.979639	116.40957
12	北京大学第三医院	39.987928	116.367035
13	北京大学第一医院	39.938945	116.387426
14	北京大学人民医院	39.942493	116.360788
15	北京协和医院	39.918987	116.422316
16	北京同仁医院	39.909173	116.425794
17	首都医科大学附属医院北京朝阳医院	39.931589	116.459657
18	北京医院	39.909989	116.421484

(3) Execute the program, enter the required number of distribution centers, here are 2 distribution centers, as shown in the figure.



(4) Display and output the results of the location of the distribution center

After the program is run, the geographic coordinates of the two distribution centers are finally obtained, and the running results are shown in the figure.



Therefore, from this result, the results of the two distribution centers can be obtained as shown in the table.

Distribution Center	Latitude	Longitude
Haidian District Distribution Center	40.065716	116.341688
Chaoyang District Distribution Center	39.876608	116.620522

3 Facility design of medical logistics distribution center

3.1 EIQ data

In the facility design of the pharmaceutical logistics distribution center, the EIQ data is first needed to calculate the target number of total orders. This design selects the actual order data of the company on April 8, 2016. The fields include the average number of orders and turnover. The specific data of days, average daily order quantity, inventory quantity, sku quantity and target order quantity are shown in the table.

年-月Year-Month	8-Apr
单均件数	1.97
周转天数	10
日均单量	14800
库存件数	?
sku数量	34000
目标单量	28000

The most important thing in designing the facilities of the distribution center is the number of shelves. The company has 4 types of shelves, among which the number of sku that can be put on the shelves, shelf efficiency, average volume of goods, storage capacity, and the proportion of units are shown in the table Show.

分类	货架类型	sku数	货架有效系数	商品平均体积	存储能力	单量占比
			m^3	m^3	件	
1	地堆位D1000*W1200*H1200	690	0.6	0.013	18.50%	30%
2	D1000*W2000*H2400	1000			39.00%	
3	D700*W1500*H2400	16400			33.00%	70%
4	D500*W1200*H2200	14600			9.50%	
合计		34000			?	

In addition to the number of shelves, the number of single and multi-piece review packing stations is also calculated. The design of the review packing station is to cooperate with the shelves for the final picking operation. The order quantity, the proportion of the order quantity, the review efficiency, and the working hours The data is shown in the table.

	订单量	单量占比	复核效率	工作小时	打包台
单件	96120	59.60%	80	10	72
多件	114410	40.40%	120	10	39

(1) The picking lane shall not be less than 800mm; the main aisle shall not be less than 3000mm

(2) The distance between the production area and the shelf area shall not be less than 6000mm

(3) The distance between the center of the operation table in the production area is 4500mm; the distance between the conveying line and the wall is not less than 1500mm

(4) The computer room and office area need to be newly built

(5) Concentration of orders at the rear of the production line

(6) The whole picking follows the light first and then the heavy

3.2 Calculation basis

3.2.1 Basic data calculation

(1) Using CAD tools to measure the area of the side wall of the CAD drawing, it can be seen that the storage area of the warehouse is approximately 21000m2. According to the area of the storage area, the approximate areas of the receiving area, storage area, production area, office area and computer room can be determined respectively.

(2) According to the average daily order quantity and target order quantity of the first table information, the number of inventory pieces can be calculated respectively. After comparison, it is found that the maximum storage capacity of the warehouse cannot meet the demand of the target order quantity, so the storage area of the warehouse Planning needs to be calculated based on the average daily order quantity.

Daily average number (pieces) = average daily order quantity * turnover days * average number of orders = 291560

(3) According to the information in the second form, the number of 4 shelves can be calculated separately

Number of shelves = average daily order quantity * storage capacity * average volume of goods / shelf effective coefficient / shelf volume.

So, the number of 4 shelves are 812, 513, 827, and 455 respectively.

(4) According to the information in the third table, the number of recheck packaging integration and multiple composite packaging stations can be calculated separately.

Packing table = order quantity * proportion of order quantity / review efficiency / working hours.

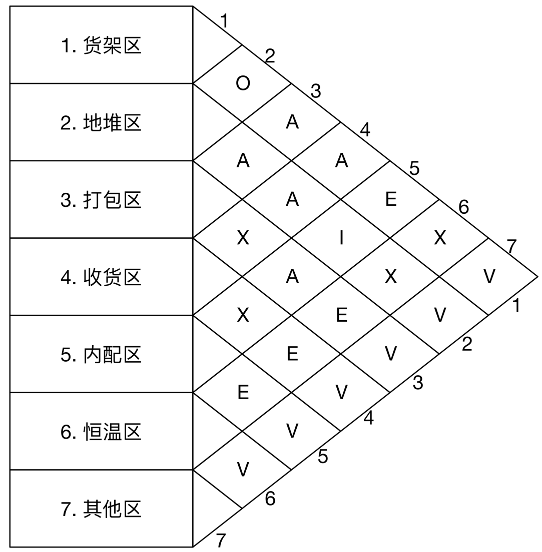
Therefore, the number of composite packaging integrated packaging stations is 72, and the number of multiple composite packaging stations is 39.

3.2.2 Planning of each functional area

For the factory layout, use the system layout design (SLP) method to plan

(1) Existing functional areas

According to the distribution of facilities in the pharmaceutical logistics distribution center, the main functional areas are divided into shelf area, stack area, packing area, receiving area, internal distribution area, constant temperature area, and other areas. The relationship table is shown in the figure.



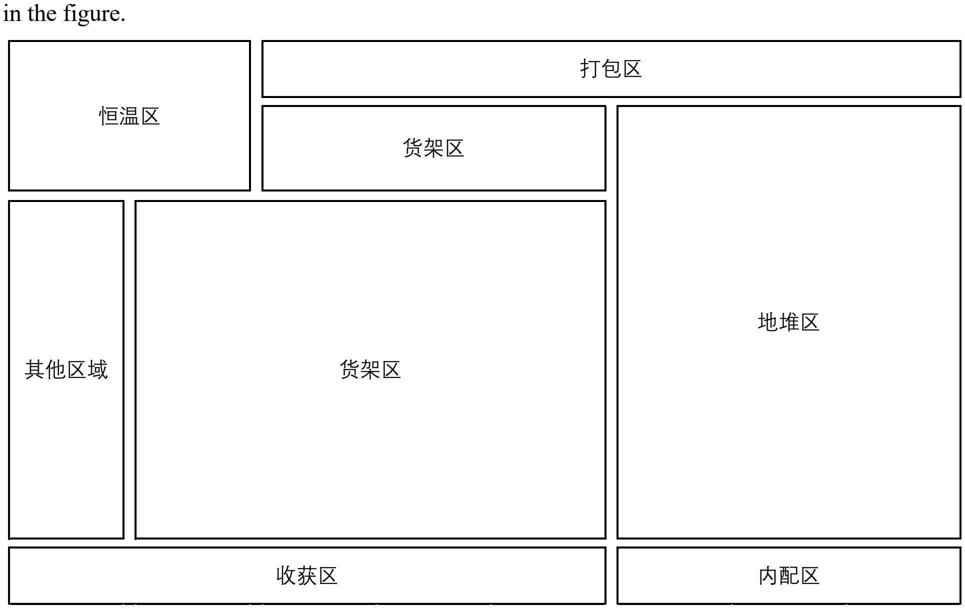
(2) Checklist of regional relations

According to the existing functional areas, the relationship checklist for each area is classified, and the relationships from important to unimportant are shown in the table.

序号	部门	接近度					
		A	E	I	O	U	X
1	货架区	3, 4	5		2	7	6
2	地堆区	3, 4		5	1	7	6
3	打包区	1, 2, 5		5		7	4, 6
4	收货区	1	6			7	3, 5
5	内配区	3	1, 6	2, 3		7	4
6	恒温区		4, 5			7	1, 2, 3
7	其他区域					1, 2, 3, 4, 5, 6, 7	

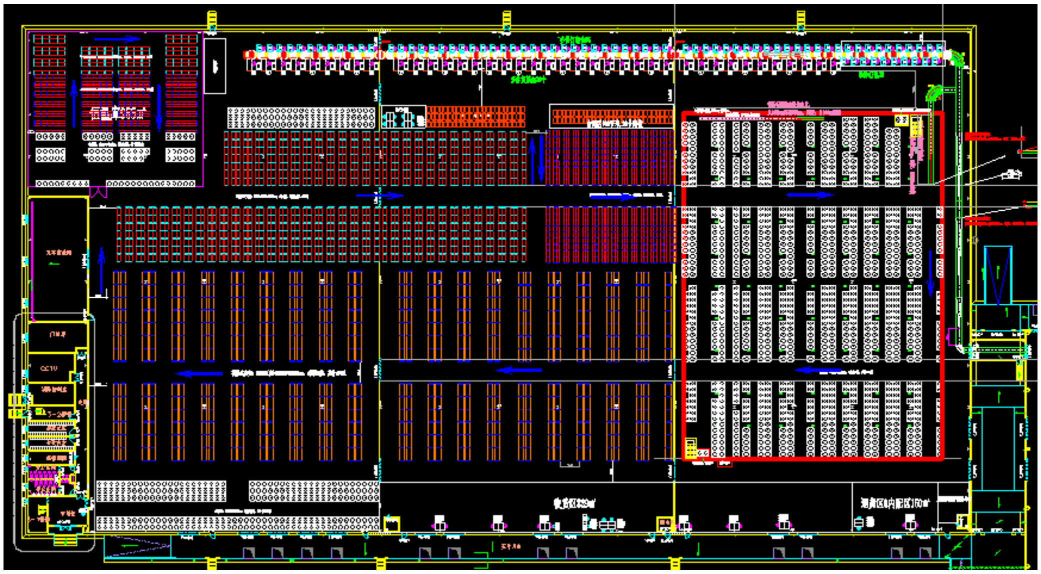
(3) Layout plan

According to the existing functional areas and the design of the checklist for the relationship between each area, the final layout plan is obtained, as shown in the figure.



3.3 Distribution center facility planning diagram

Based on the above planning and analysis, Auto CAD is used as an auxiliary tool, and the standard shelf and packing table legends are used as the standard to draw the final distribution center facility planning diagram, as shown in the figure.

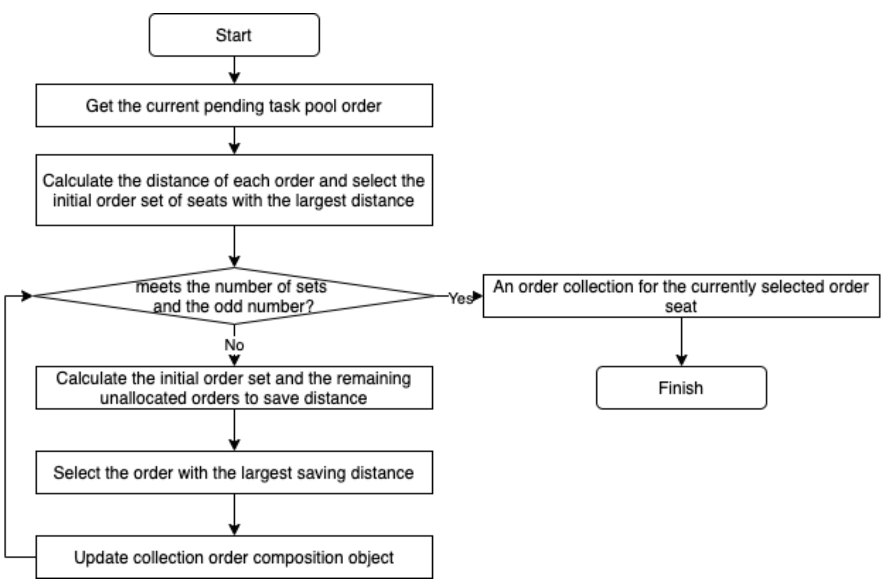


4 Optimization of picking strategy for pharmaceutical logistics

4.1 Group collective single strategy-mileage saving algorithm

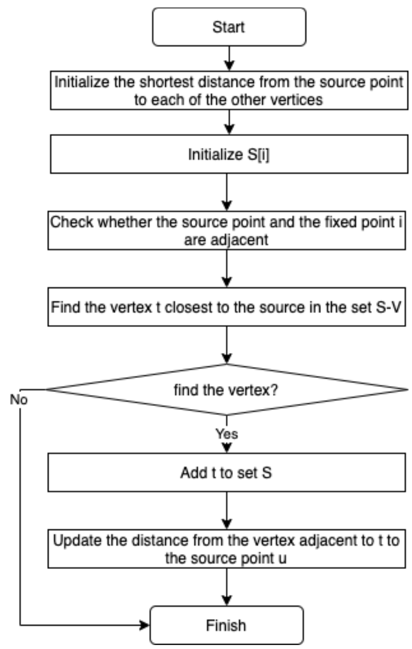
4.1.1 Flow chart of mileage saving algorithm

First obtain the current pending task pool orders, and then calculate the distance of each order. First, the order with the maximum distance is used as the initial collective order. If the requirements are met, the currently selected order is used as a collective order. If the requirements are not met, the remaining orders Calculate the saving distance for the unallocated orders, and then select the order with the largest saving distance and update it as a new set of order composition objects. The flow chart of the mileage saving algorithm is shown in the figure.



4.1.2 Core function design

Using the mileage saving algorithm is to group the existing 2047 orders. The flow chart of the mileage saving algorithm is shown in the figure.



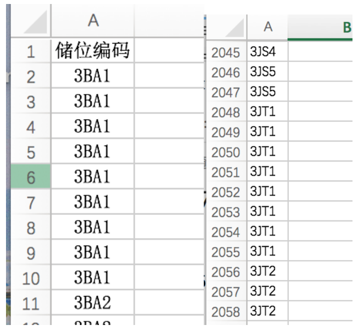
In the core code summary of the mileage saving algorithm, first initialize the shortest distance from the source point to each other order, check whether the source point and the vertex are adjacent, find the vertex closest to the source point in the set, and if the order is found, add the time Set the distance, and then update the distance from the adjacent vertex to the source point. If the vertex is not found, the program ends. The core code of the algorithm is shown in the figure.

```
for (int i = 1; i < n; i++) {
  dist[i] = c[u][i];                          //初始化源点到其他各顶点的最短距离
  s[i] = false;                               //s[i]全部初始化为FALSE，在之后可以更改
  if (dist[i] == 10000){
    p[i] = -1;                                //满足条件说明源点和顶点i不相邻
    else                                      //满足条件源点和顶点i相邻，设置p[i]=u;
    p[i] = u;
  }
  dist[u] = 0;
  s[u] = true;
  for (int i = 1; i < n; i++) {
    float temp = 10000;
    int t = u;
  for (int j = 1; j < n; j++) {
    if ((!s[j]) && (dist[j] < temp))          //在集合S-V中寻找离源点最近的顶点t
    {
      temp = dist[j];
      t = j;
    }
    if (t == u) break;                        //找不到t则跳出循环
      s[t] = true;                            //否则将t加入集合S
    for (j = 1; j < n; j++)                   //更新与t相邻的顶点到原点u的距离
    if ((!s[j]) && (c[t][j])) {
      dist[j] = dist[t] + c[t][j];
      p[j] = t;
    }
   }
}
```

4.1.3 Input and output

(1) Input file order.xls

First, enter the storage code of all the order items into the Excel table. At this time, the order of storage code is random. Store the Excel file in the "C:/Order/" path, as shown in the figure.



	A
1	储位编码
2	3BA1
3	3BA1
4	3BA1
5	3BA1
6	3BA1
7	3BA1
8	3BA1
9	3BA1
10	3BA1
11	3BA2

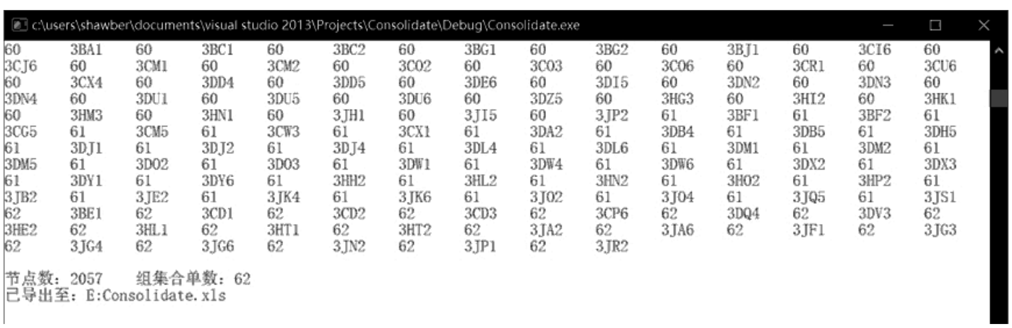
	A	B
2045	3JS4	
2046	3JS5	
2047	3JS5	
2048	3JT1	
2049	3JT1	
2050	3JT1	
2051	3JT1	
2052	3JT1	
2053	3JT1	
2054	3JT1	
2055	3JT1	
2056	3JT2	
2057	3JT2	
2058	3JT2	

(2) Import storage code data: the program will read the content in the "order.xlsx" file from "C:/Order/" by default, the code is shown in the figure.

```
void loadfile() {
    loadPathInfo("C:\\Order\\order.xlsx");
    test(1,99999);
}
```

(3) Program execution output consolidated.exe

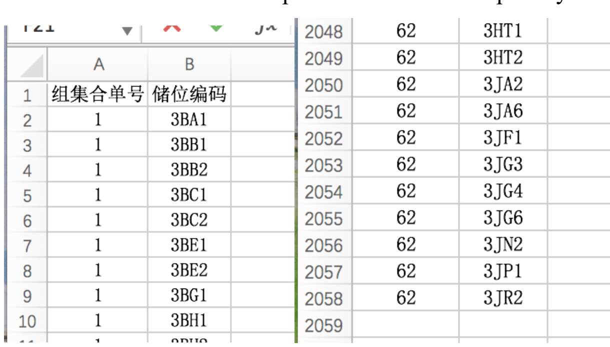
The purpose of this code execution is to use the mileage-saving algorithm to group the order into the group list operation, and in this design process, the corresponding storage code is combined to generate 62 group list from 2057 nodes. The picking path of the algorithm is better than that of the old algorithm, and the output result of the algorithm is shown in the figure.



```
c:\users\shawber\documents\visual studio 2013\Projects\Consolidate\Debug\Consolidate.exe
60    3BA1  60    3BC1  60    3BC2  60    3BG1  60    3BG2  60    3BJ1  60    3CI6  60
3CJ6  60    3CM1  60    3CM2  60    3CO2  60    3CO3  60    3CO6  60    3CR1  60    3CU6
60    3CX4  60    3DD4  60    3DD5  60    3DE6  60    3DI5  60    3DN2  60    3DN3  60
3DN4  60    3DU1  60    3DU5  60    3DU6  60    3DZ5  60    3HG3  60    3HI2  60    3HK1
60    3HM3  60    3HN1  60    3JH1  60    3JI5  60    3JP2  61    3BF1  61    3BF2  61
3CG5  61    3CM5  61    3CW3  61    3CX1  61    3DA2  61    3DB4  61    3DB5  61    3DH5
61    3DJ1  61    3DJ2  61    3DJ4  61    3DL4  61    3DL6  61    3DM1  61    3DM2  61
3DM5  61    3DO2  61    3DO3  61    3DW1  61    3DW4  61    3DW6  61    3DX2  61    3DX3
61    3DY1  61    3DY6  61    3HH2  61    3HL2  61    3HN2  61    3HO2  61    3HP2  61
3JB2  61    3JE2  61    3JK4  61    3JK6  61    3JO2  61    3JO4  61    3JQ5  61    3JS1
62    3BE1  62    3CD1  62    3CD2  62    3CD3  62    3CP6  62    3DQ4  62    3DV3  62
3HE2  62    3HL1  62    3HT1  62    3HT2  62    3JA2  62    3JA6  62    3JF1  62    3JG3
62    3JG4  62    3JG6  62    3JN2  62    3JP1  62    3JR2

节点数: 2057    组集合单数: 62
已导出至: E:Consolidate.xls
```

(4) The output file consolidated.xls

Output the data of the running algorithm to another Excel, match the group collection order number with the storage code, and the conclusion drawn is the order of the group collection order. The file will be output to the "C:/Order/" path by default. As shown in the figure.



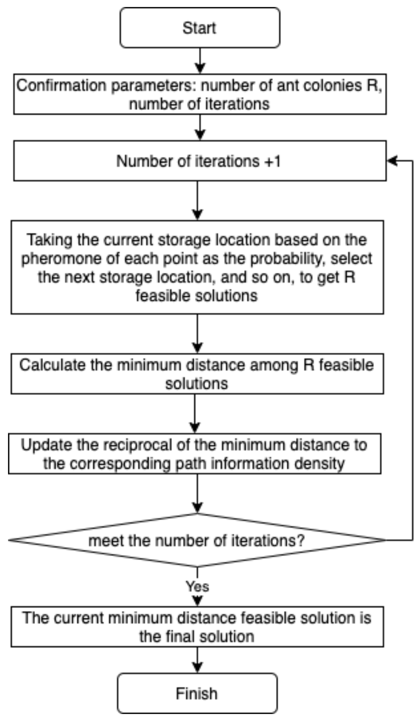
	A	B
1	组集合单号	储位编码
2	1	3BA1
3	1	3BB1
4	1	3BB2
5	1	3BC1
6	1	3BC2
7	1	3BE1
8	1	3BE2
9	1	3BG1
10	1	3BH1

2048	62	3HT1
2049	62	3HT2
2050	62	3JA2
2051	62	3JA6
2052	62	3JF1
2053	62	3JG3
2054	62	3JG4
2055	62	3JG6
2056	62	3JN2
2057	62	3JP1
2058	62	3JR2
2059		

4.2 Optimization of Picking Order-Ant Colony Algorithm

4.2.1 Flow chart of ant colony algorithm

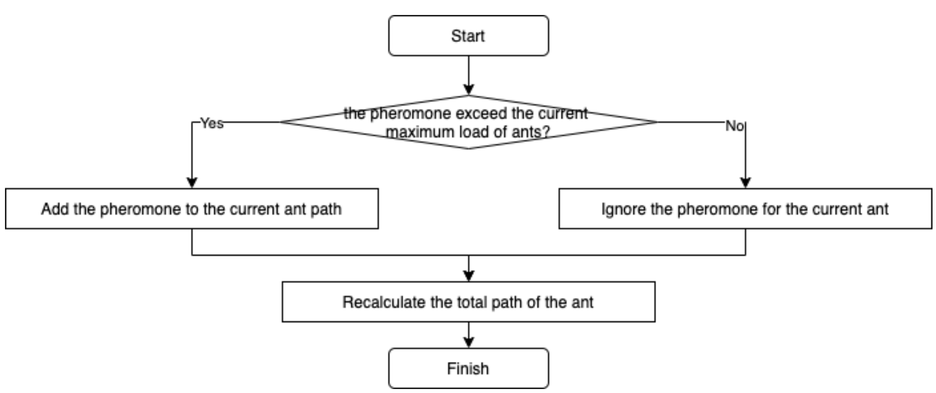
First confirm the number of ant colonies and the number of iterations, the number of iterations is continuously increased by 1, and the next storage position is selected based on the pheromone of each point as the probability of the current storage position, and so on, a feasible solution is obtained, and then the minimum distance is calculated according to the feasible solution. Then update the reciprocal of the minimum distance to the information concentration and output the result if the shortest path is satisfied, otherwise iterate again. The flow chart of the ant colony algorithm is shown in the figure.



4.2.2 Core function design

(1) Add new pheromone to the path

The walking of ants carries pheromone, and the core idea of ant colony algorithm is to carry effective pheromone to spread effective ants, so it is more important to judge whether the ant can carry pheromone, add new pheromone to the path The program flow chart is shown in the figure.

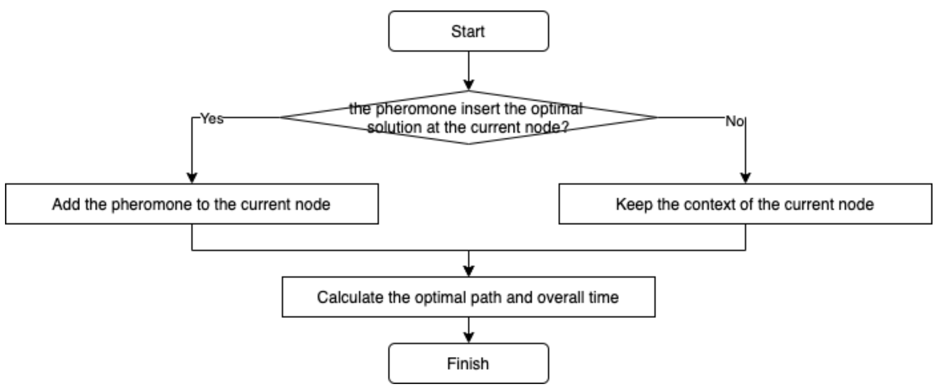


In adding a new pheromone to the path, first determine whether the pheromone exceeds the maximum load of the current ant, if it exceeds, add the pheromone to the ant path, otherwise ignore the pheromone for the current ant, and then recalculate the total ant load. Path, the core code is shown in the figure.

```
for(ant=0;ant<RANK_W-1;ant++){
  for(i=0;i<MAX_ORDERS;i++){
    if( i < MAX_ORDERS-1 ){                                    //判断该信息素是否超过当前蚂蚁最大负载
      from = rankAnts[ant].path[i];                            //若最优，则将其加入到蚂蚁路径中
      to = rankAnts[ant].path[i+1];
    }
  else{
    from = rankAnts[ant].path[i];                              //否则忽略该信息素
    to = rankAnts[ant].path[0];
  }
  phero[from][to] +=(RANK_W - ant)*(QVAL/ rankAnts[ant].tourLength) ;   //计算单个蚂蚁行走距离
  phero[to][from] = phero[from][to];
  }
}
```

(2) Add the optimal path

With effective pheromone, finding the optimal path based on the pheromone is also the most important thing. Therefore, it is necessary to judge which two nodes the pheromone is inserted between is the best, so the program flow chart for adding the optimal path is shown in the figure Shown.



In adding the optimal path, first judge whether the pheromone is optimally inserted in the current node, if so, insert the modified pheromone between the two nodes, otherwise keep the context of the current node, and then calculate the optimal path and the overall Time, the core algorithm is shown in the figure.

```
for(i = 0;i<MAX ORDERS;i++){
   if( i < MAX ORDERS-1 ){
     from = ants[bestIndex].path[i];          //蚂蚁经过的上一个节点
     to = ants[bestIndex].path[i+1];          //蚂蚁经过的下一个节点
  }
   else{
    from = ants[bestIndex].path[i];
    to = ants[bestIndex].path[0];
  }
  phero[from][to] +=(QVAL/ best) ;            //计算最优路径
  phero[to][from] = phero[from][to];
}
for (from=0; from < MAX ORDERS;from++){
  for( to=0; to<MAX ORDERS; to++){
    phero[from][to] *= RHO;                   //计算整体时间
     }
}
```

4.2.3 Input and output

(1) Input file consolidated.xls

Enter the Excel conclusion drawn by the previous mileage saving algorithm into the algorithm of the picking strategy. After successfully running the mileage saving algorithm, the file has been stored in the "C:/Order/" path, as shown in the figure.

	A	B
1	组集合单号	储位编码
2	1	3BA1
3	1	3BB1
4	1	3BB2
5	1	3BC1
6	1	3BC2
7	1	3BE1
8	1	3BE2
9	1	3BG1
10	1	3BH1

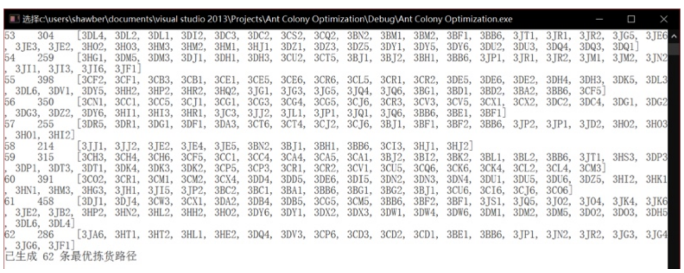
(2) Import group set list data

The program will read the contents of the "consolidate.xlsx" file from "C:/Order/" by default. The file contains the group collection order number and storage code information of 62 group collection orders. The imported code is shown in the figure.

```
void loadfile() {
    loadPathInfo("C:\\Order\\consolidate.xlsx");
    test(1,99999);
}
```

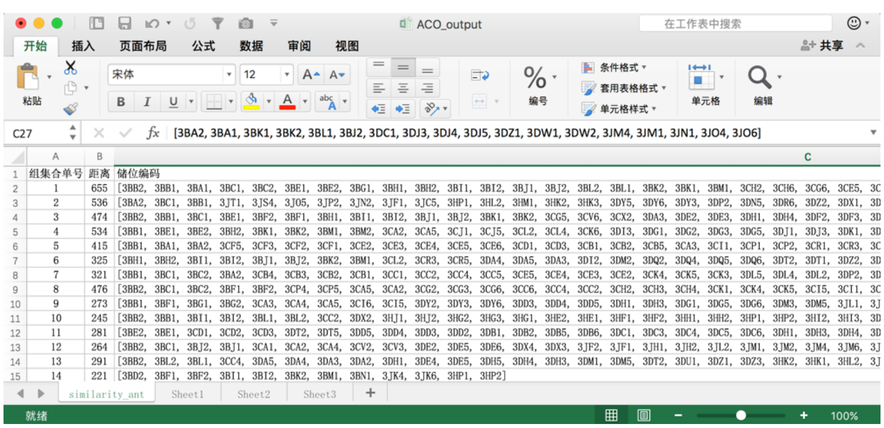
(3) The program executes Ant Colony Optimization.exe

This algorithm uses the idea of ant colony algorithm to further optimize the picking path of the previously generated 62 group sets. The final conclusion drawn after the combination of the two algorithms is optimal, and the execution result is shown in the figure.



(4) Output file ACO_output.xls

This algorithm outputs the distance traveled by each group set and the stored position code passed. From then on, it can be compared with the old algorithm. The Excel file of the output result is shown in the figure.

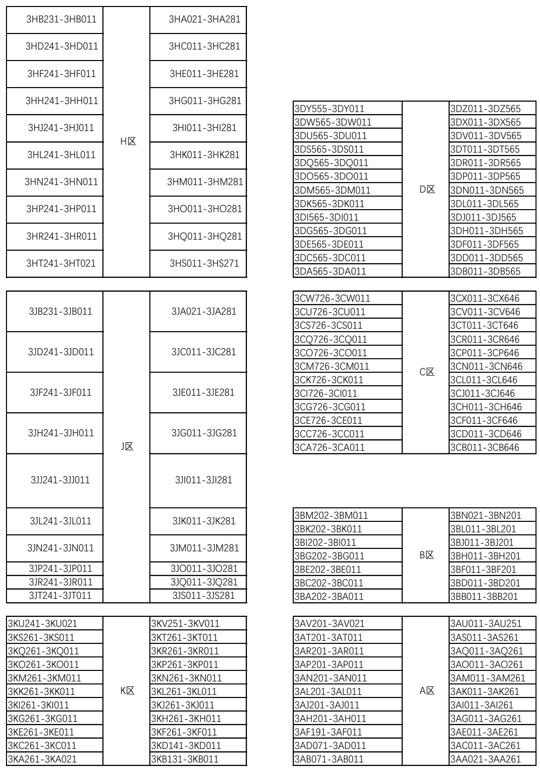


4.3 Simulation model verification

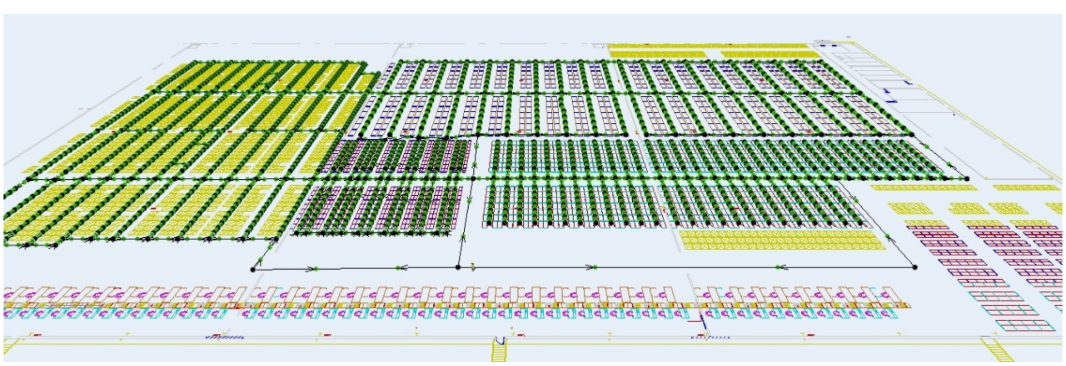
4.3.1 FlexSim model building

First, partition the various shelves of the planned warehouse, and name the storage locations in each area, as shown in the figure below. There are different partitions. Take the storage location code 3HB231 as an example. 3 represents the warehouse number, H represents the area, B represents the shelf code, 2 represents the second row, and 31 represents the number.

Then import this CAD drawing into FlexSim, add a flow node to each shelf and name it according to the plan as a storage point for modeling. Connect each flow node by "A + left mouse button" to form a complete and closed flow to simulate the path taken by the picker; specify a point as the starting node, and finally add a worker entity as the picker Cargo clerk.



The 1:1 warehouse simulation model is shown in the figure. There will be a flow node between every two storage positions as the node where the pickers stay. The constant temperature storage area and the ground storage area are temporarily not included in the simulation object for consideration, any node Both can be linked to the review packing table, and the display on the interface and the walking in the path are consistent with the actual warehouse.



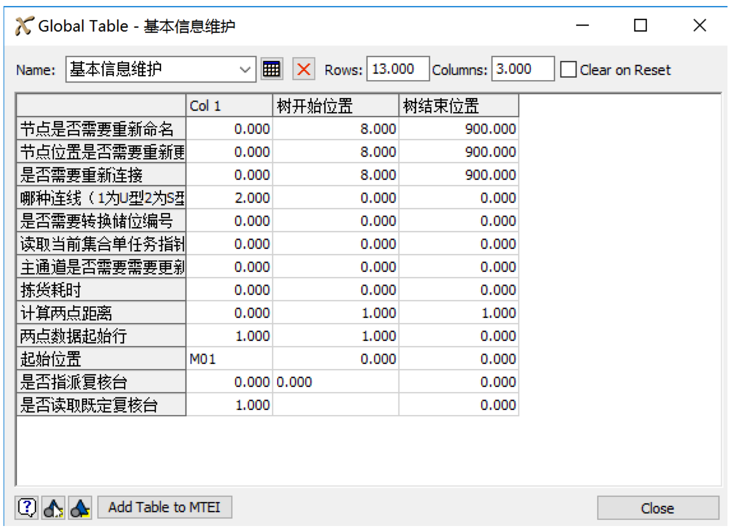
4.3.2 Global table creation

The global table plays an important role in FlexSim. All the definitions of a simulation model, such as walking route, path sequence, etc., must be completed through the global table, and all mandatory actions are also operated through the global table. The global table to be established for this simulation model is shown below.

(1) Maintenance of basic information

The main field of the table is Col1-used to define basic information, the starting position of the tree and the ending position of the tree.

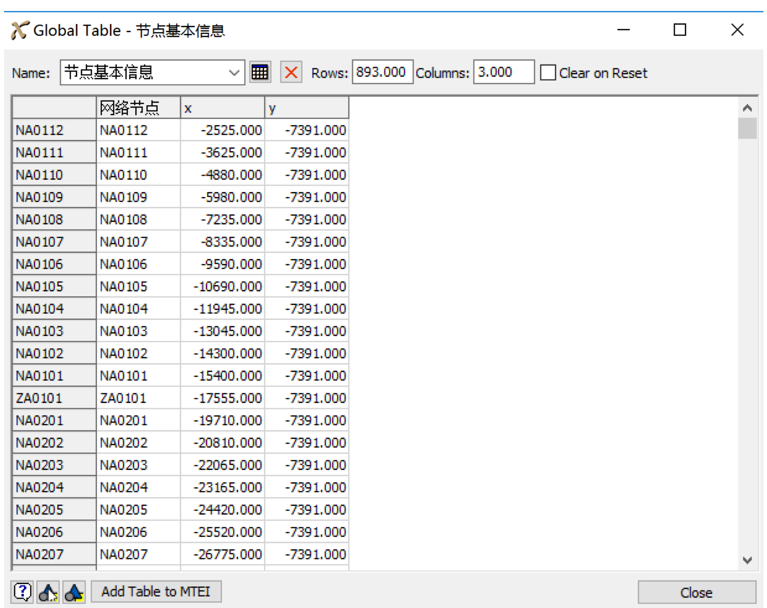
The main information defined in this table includes "whether the node needs to be renamed", "whether the node location needs to be re-updated", "whether it needs to be reconnected", "what kind of connection (1 is U-shaped and 2 is S-shaped)", "whether Need to convert the storage number", "Read the current set of single task pointer", "Does the main channel need to be updated", "Picking time", "Calculate the distance between two points", "Two point data start line", "Start The basic information maintenance table is shown in the figure for “Starting position”, “Whether to assign a composite station", and “Whether to read an established composite station”.



	Col 1	树开始位置	树结束位置
节点是否需要重新命名	0.000	8.000	900.000
节点位置是否需要重新更	0.000	8.000	900.000
是否需要重新连接	0.000	8.000	900.000
哪种连线（1为U型2为S型	2.000	0.000	0.000
是否需要转换储位编号	0.000	0.000	0.000
读取当前集合单任务指针	0.000	0.000	0.000
主通道是否需要需要更新	0.000	0.000	0.000
拣货耗时	0.000	0.000	0.000
计算两点距离	0.000	1.000	1.000
两点数据起始行	1.000	1.000	0.000
起始位置	M01	0.000	0.000
是否指派复核台	0.000	0.000	0.000
是否读取既定复核台	1.000		0.000

(2) Basic information of the node

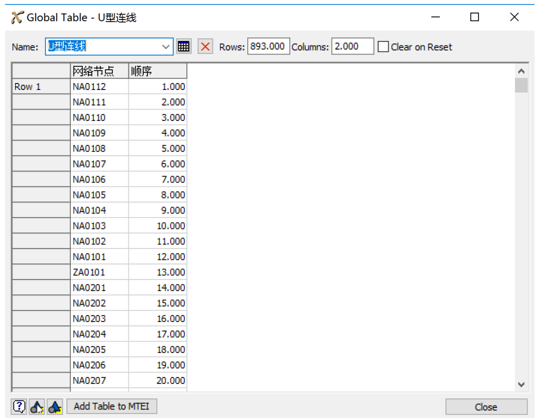
The global table has entered the information and specific coordinates of all network nodes, as shown in the figure.



	网络节点	x	y
NA0112	NA0112	-2525.000	-7391.000
NA0111	NA0111	-3625.000	-7391.000
NA0110	NA0110	-4880.000	-7391.000
NA0109	NA0109	-5980.000	-7391.000
NA0108	NA0108	-7235.000	-7391.000
NA0107	NA0107	-8335.000	-7391.000
NA0106	NA0106	-9590.000	-7391.000
NA0105	NA0105	-10690.000	-7391.000
NA0104	NA0104	-11945.000	-7391.000
NA0103	NA0103	-13045.000	-7391.000
NA0102	NA0102	-14300.000	-7391.000
NA0101	NA0101	-15400.000	-7391.000
ZA0101	ZA0101	-17555.000	-7391.000
NA0201	NA0201	-19710.000	-7391.000
NA0202	NA0202	-20810.000	-7391.000
NA0203	NA0203	-22065.000	-7391.000
NA0204	NA0204	-23165.000	-7391.000
NA0205	NA0205	-24420.000	-7391.000
NA0206	NA0206	-25520.000	-7391.000
NA0207	NA0207	-26775.000	-7391.000

(3) U-shaped connection

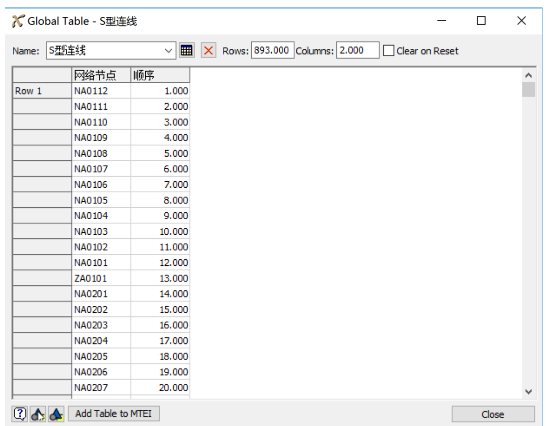
The global table sorts the network nodes so that it forms a U-shaped route for the pickers' walking, as shown in the figure.



	网络节点	顺序
Row 1	NA0112	1.000
	NA0111	2.000
	NA0110	3.000
	NA0109	4.000
	NA0108	5.000
	NA0107	6.000
	NA0106	7.000
	NA0105	8.000
	NA0104	9.000
	NA0103	10.000
	NA0102	11.000
	NA0101	12.000
	ZA0101	13.000
	NA0201	14.000
	NA0202	15.000
	NA0203	16.000
	NA0204	17.000
	NA0205	18.000
	NA0206	19.000
	NA0207	20.000

(4) S type connection

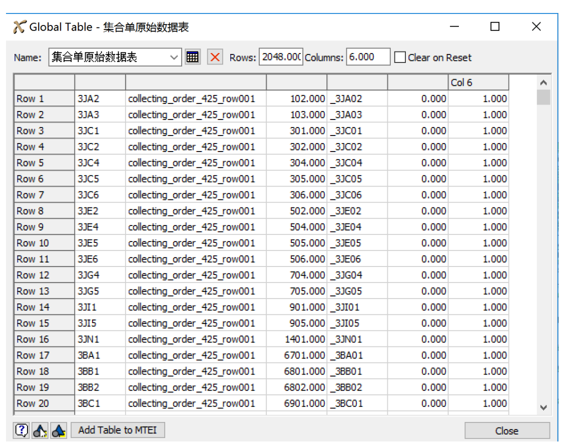
The global table sorts the network nodes so that it forms an S-shaped route for the pickers' walking, as shown in the figure.



	网络节点	顺序
Row 1	NA0112	1.000
	NA0111	2.000
	NA0110	3.000
	NA0109	4.000
	NA0108	5.000
	NA0107	6.000
	NA0106	7.000
	NA0105	8.000
	NA0104	9.000
	NA0103	10.000
	NA0102	11.000
	NA0101	12.000
	ZA0101	13.000
	NA0201	14.000
	NA0202	15.000
	NA0203	16.000
	NA0204	17.000
	NA0205	18.000
	NA0206	19.000
	NA0207	20.000

(5) Collection list original data table

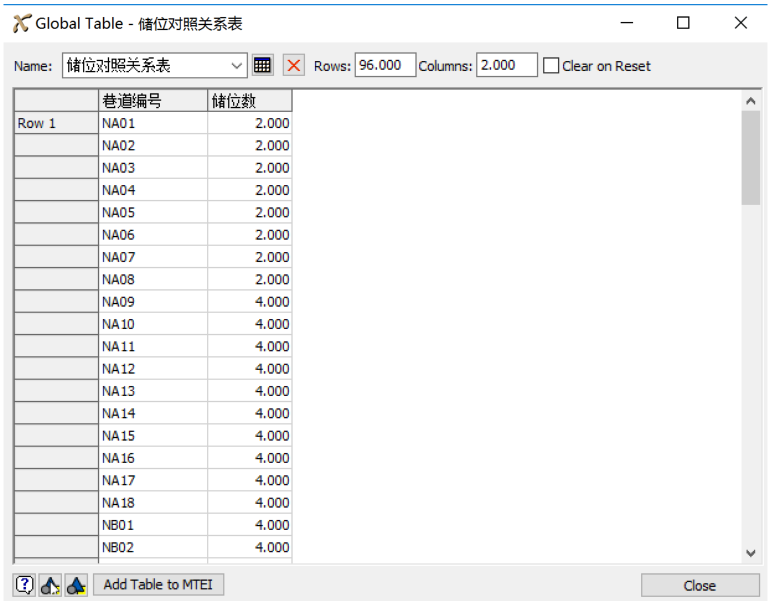
Here is a global table that needs to be manually entered. Enter the converted group set list and the corresponding storage number into this global table. The fields in the first column are storage fields, the fields in the second column are the name of the group set list, the fields in the third column are the generated storage codes, and the fields in the fourth column are the storage fields named by FlexSim. The fifth column has no practical meaning. The original value of the six columns is 0. With the picking operation of the picker, the number 0 will change to the number 1, which proves that the collective order picking is completed, as shown in the figure



						Col 6
Row 1	3JA2	collecting_order_425_row001	102.000	_3JA02	0.000	1.000
Row 2	3JA3	collecting_order_425_row001	103.000	_3JA03	0.000	1.000
Row 3	3JC1	collecting_order_425_row001	301.000	_3JC01	0.000	1.000
Row 4	3JC2	collecting_order_425_row001	302.000	_3JC02	0.000	1.000
Row 5	3JC4	collecting_order_425_row001	304.000	_3JC04	0.000	1.000
Row 6	3JC5	collecting_order_425_row001	305.000	_3JC05	0.000	1.000
Row 7	3JC6	collecting_order_425_row001	306.000	_3JC06	0.000	1.000
Row 8	3JE2	collecting_order_425_row001	502.000	_3JE02	0.000	1.000
Row 9	3JE4	collecting_order_425_row001	504.000	_3JE04	0.000	1.000
Row 10	3JE5	collecting_order_425_row001	505.000	_3JE05	0.000	1.000
Row 11	3JE6	collecting_order_425_row001	506.000	_3JE06	0.000	1.000
Row 12	3JG4	collecting_order_425_row001	704.000	_3JG04	0.000	1.000
Row 13	3JG5	collecting_order_425_row001	705.000	_3JG05	0.000	1.000
Row 14	3JI1	collecting_order_425_row001	901.000	_3JI01	0.000	1.000
Row 15	3JI5	collecting_order_425_row001	905.000	_3JI05	0.000	1.000
Row 16	3JN1	collecting_order_425_row001	1401.000	_3JN01	0.000	1.000
Row 17	3BA1	collecting_order_425_row001	6701.000	_3BA01	0.000	1.000
Row 18	3BB1	collecting_order_425_row001	6801.000	_3BB01	0.000	1.000
Row 19	3BB2	collecting_order_425_row001	6802.000	_3BB02	0.000	1.000
Row 20	3BC1	collecting_order_425_row001	6901.000	_3BC01	0.000	1.000

(6) Storage location comparison table

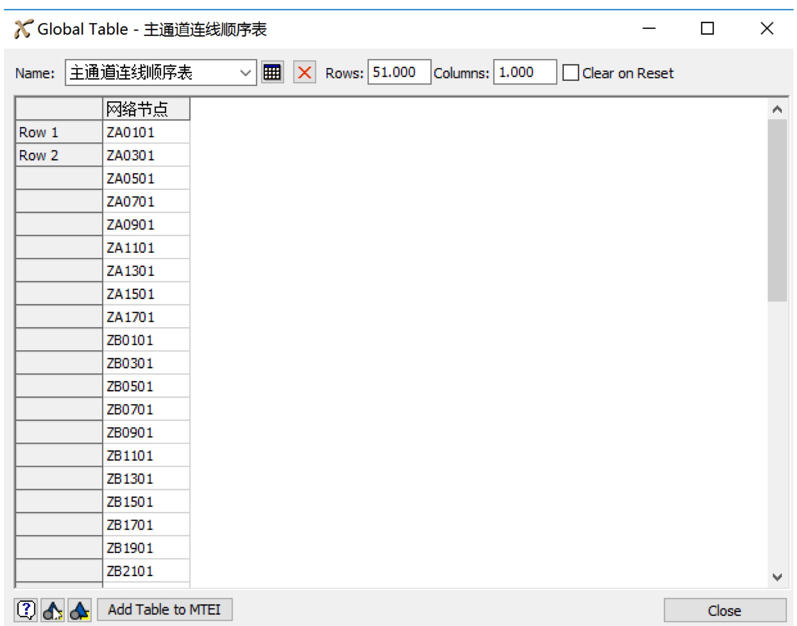
The number of storage locations corresponding to the lane number is named here. The storage location numbers here are all corners and other junctions, as shown in the figure.



	巷道编号	储位数
Row 1	NA01	2.000
	NA02	2.000
	NA03	2.000
	NA04	2.000
	NA05	2.000
	NA06	2.000
	NA07	2.000
	NA08	2.000
	NA09	4.000
	NA10	4.000
	NA11	4.000
	NA12	4.000
	NA13	4.000
	NA14	4.000
	NA15	4.000
	NA16	4.000
	NA17	4.000
	NA18	4.000
	NB01	4.000
	NB02	4.000

(7) Main channel connection sequence table

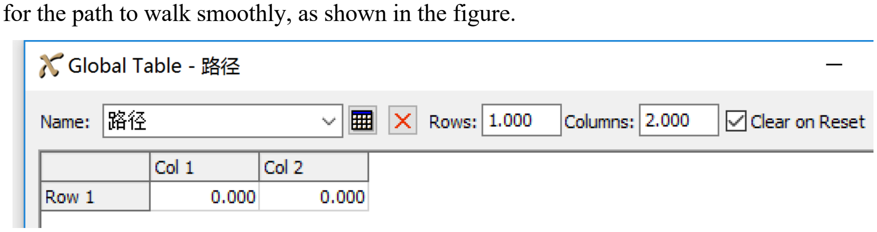
The global table connects the number of the main channel so that the node can pass smoothly, as shown in the figure.



	网络节点
Row 1	ZA0101
Row 2	ZA0301
	ZA0501
	ZA0701
	ZA0901
	ZA1101
	ZA1301
	ZA1501
	ZA1701
	ZB0101
	ZB0301
	ZB0501
	ZB0701
	ZB0901
	ZB1101
	ZB1301
	ZB1501
	ZB1701
	ZB1901
	ZB2101

(8) Path

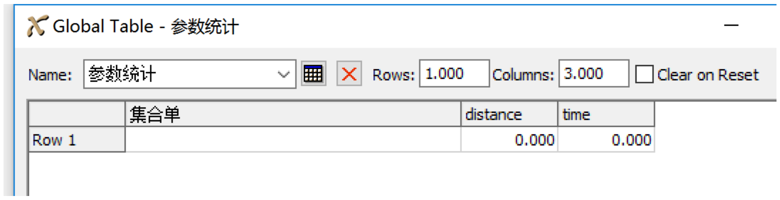
The definition of this is for the path to walk smoothly, as shown in the figure.



	Col 1	Col 2
Row 1	0.000	0.000

(9) Parameter statistics

The output here is the result obtained in the global table (5). The first column is the name of the collection order, the second column is the distance traveled by the collection order to complete the picking, and the third column is the collection order picking completion. The time used is shown in the figure.



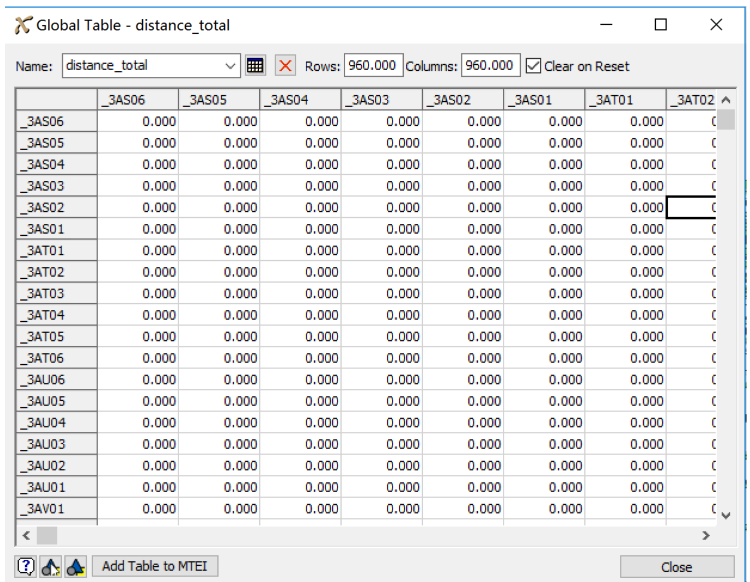
Global Table - 参数统计

Name: 参数统计 Rows: 1.000 Columns: 3.000 Clear on Reset

	集合单	distance	time
Row 1		0.000	0.000

(10) distance_total

The global table defines the distance traveled between each storage position, as shown in the figure.



Global Table - distance_total

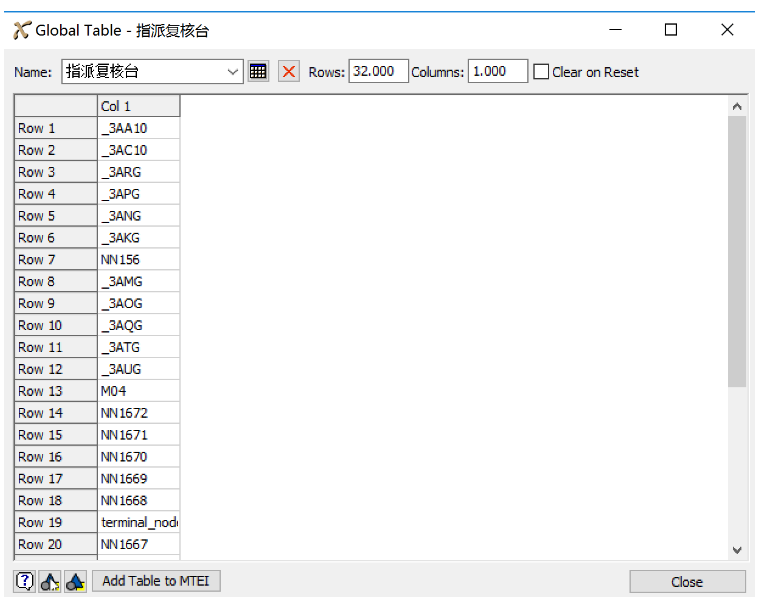
Name: distance_total Rows: 960.000 Columns: 960.000 Clear on Reset

	_3AS06	_3AS05	_3AS04	_3AS03	_3AS02	_3AS01	_3AT01	_3AT02
_3AS06	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AS05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AS04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AS03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AS02	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AS01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AT01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AT02	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AT03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AT04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AT05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AT06	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AU06	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AU05	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AU04	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AU03	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AU02	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AU01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(
_3AV01	0.000	0.000	0.000	0.000	0.000	0.000	0.000	(

Add Table to MTEI Close

(11) Assign a composite station

The global table defines the positions of the review packing stations to be allocated by different storage nodes, as shown in the figure.



Global Table - 指派复核台

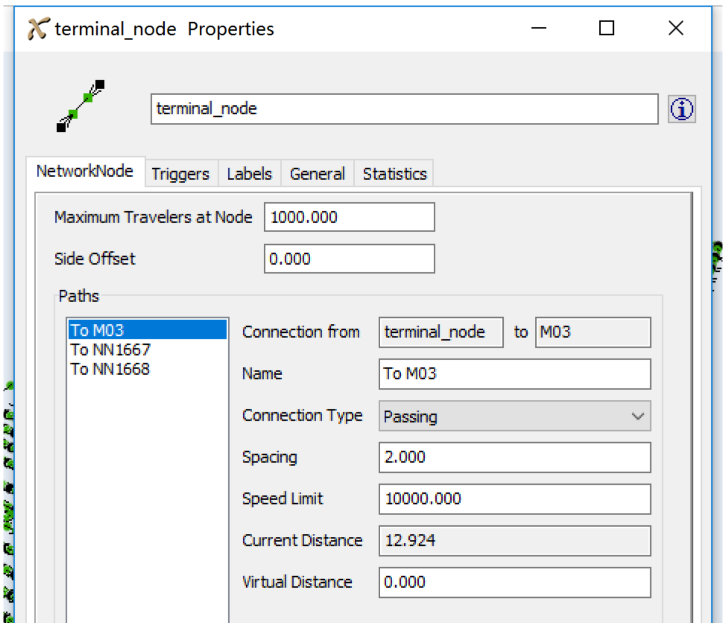
Name: 指派复核台 Rows: 32.000 Columns: 1.000 Clear on Reset

	Col 1
Row 1	_3AA10
Row 2	_3AC10
Row 3	_3ARG
Row 4	_3APG
Row 5	_3ANG
Row 6	_3AKG
Row 7	NN156
Row 8	_3AMG
Row 9	_3AOG
Row 10	_3AQG
Row 11	_3ATG
Row 12	_3AUG
Row 13	M04
Row 14	NN1672
Row 15	NN1671
Row 16	NN1670
Row 17	NN1669
Row 18	NN1668
Row 19	terminal_nodi
Row 20	NN1667

Add Table to MTEI Close

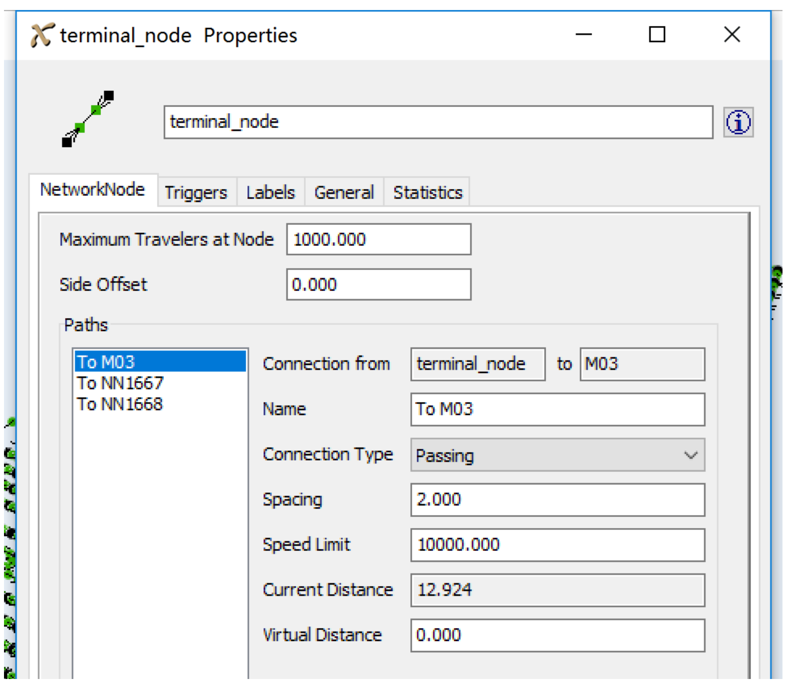
4.3.3 Node establishment

This node is named terminal_node, which is the starting point of the model. The special definition of this node mainly lies in the initial value. The algorithm is linked to the global table "parameter statistics". All definitions of this initial point are connected to the global table, so that The first order of the first group collection order is formed at this starting point, and then the picker walks from this starting point according to the ant colony algorithm, and the next collection orders will be based on the picker's previous collection order The end point is set up, and the route is optimized through the defined ant colony algorithm. Finally, the picker completes all the collection orders of all orders. The basic information of this node is shown in the figure.



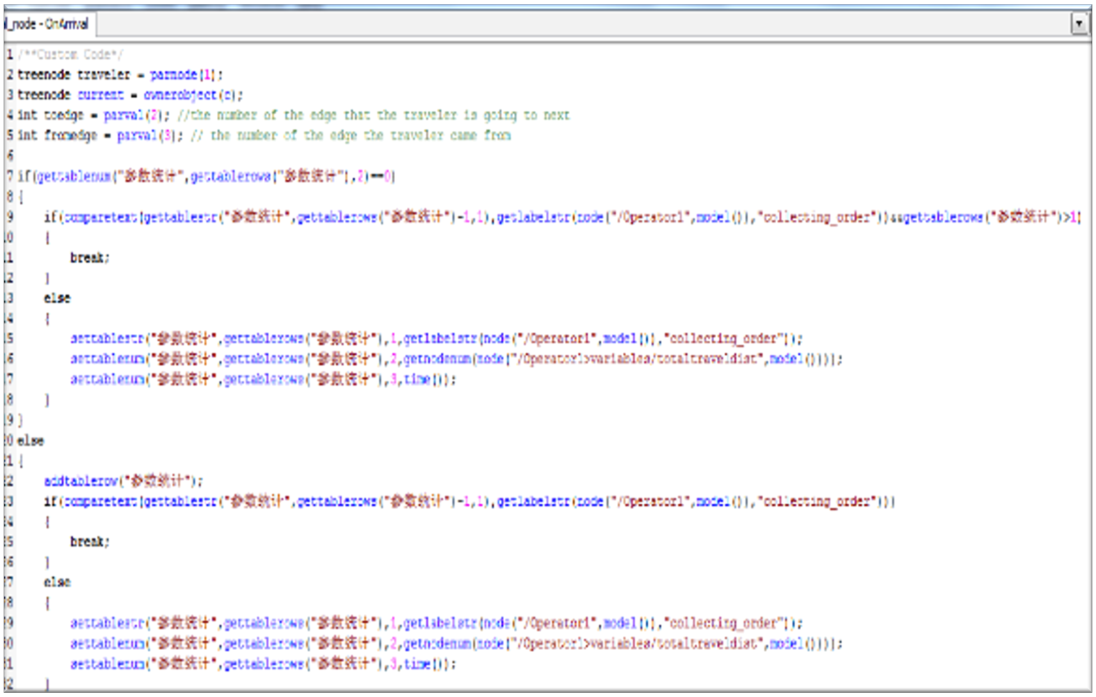
(1) OnReset——initial definition

This definition makes all the information of the initial node follow the global table "parameter statistics", the code is shown in the figure.



(2) OnArrival——The path definition for each pass

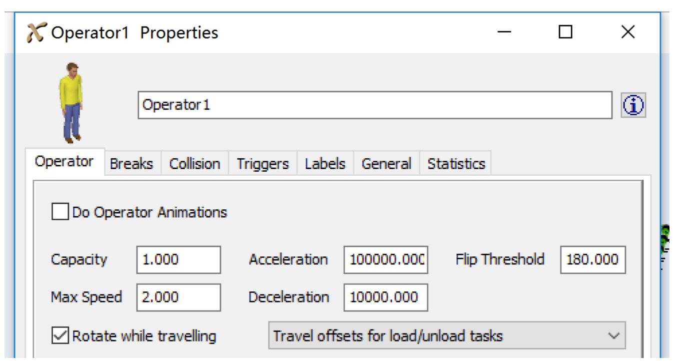
Changing the code also means walking through the information of parameter statistics, and the code information is shown in the figure.



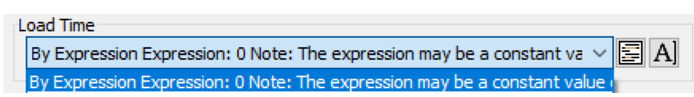
```
_node - OnArrival
/**Custom Code*/
treenode traveler = parnode(1);
treenode current = ownerobject(c);
int toedge = parval(2); //the number of the edge that the traveler is going to next
int fromedge = parval(3); // the number of the edge the traveler came from

if(gettablenum("参数统计",gettablerows("参数统计"),2)==0)
{
    if(comparetext(gettablestr("参数统计",gettablerows("参数统计")-1,1),getlabelstr(node("/Operator1",model()),"collecting_order"))&&gettablerows("参数统计")>1)
    {
        break;
    }
    else
    {
        settablestr("参数统计",gettablerows("参数统计"),1,getlabelstr(node("/Operator1",model()),"collecting_order"));
        settablenum("参数统计",gettablerows("参数统计"),2,getnodenum(node("/Operator1>variables/totaltraveldist",model())));
        settablenum("参数统计",gettablerows("参数统计"),3,time());
    }
}
else
{
    addtablerow("参数统计");
    if(comparetext(gettablestr("参数统计",gettablerows("参数统计")-1,1),getlabelstr(node("/Operator1",model()),"collecting_order")))
    {
        break;
    }
    else
    {
        settablestr("参数统计",gettablerows("参数统计"),1,getlabelstr(node("/Operator1",model()),"collecting_order"));
        settablenum("参数统计",gettablerows("参数统计"),2,getnodenum(node("/Operator1>variables/totaltraveldist",model())));
        settablenum("参数统计",gettablerows("参数统计"),3,time());
    }
```

4.3.4 Create Picker

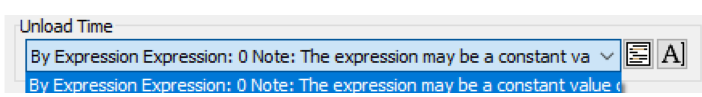
The picker of this model is defined as Operator 1, indicating that this is one of many pickers in the warehouse. The maximum speed of this picker (Max Speed) is defined as 2m/s, and the maximum capacity is every time The maximum number of orders for sorting (Capacity) is defined as 1 order, and the basic information of the picker is shown in the figure.



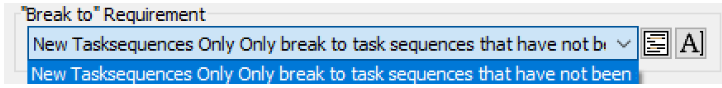
(1) Load Time:



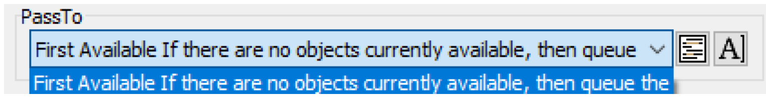
(2) Unload Time:



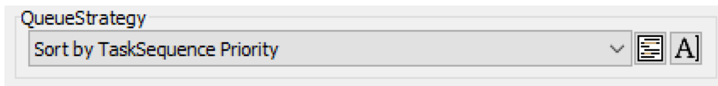
(3) Break to Requirement



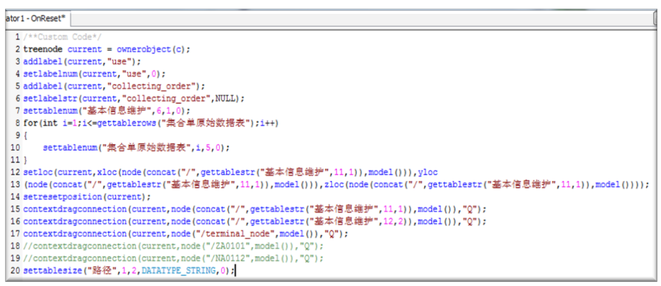
(4) Pass To:



(5) Queue Strategy



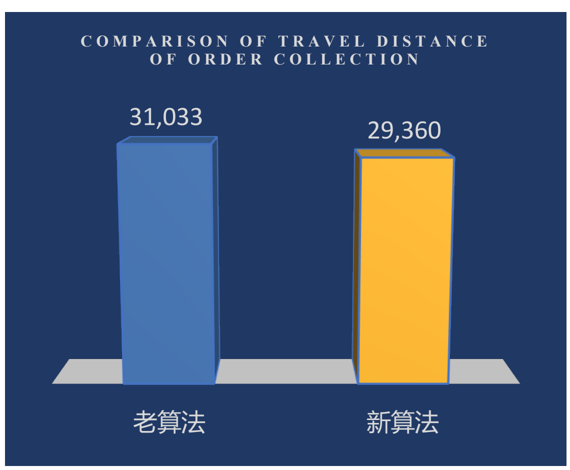
For the definition of the initial action (OnReset), it is also to be connected to the "maintenance of basic information" and the "collection order original data table" of the global table. The orders in the group collection order are picked according to the information in the global table. The information in the table is used for path walking, and the code is shown in the figure.



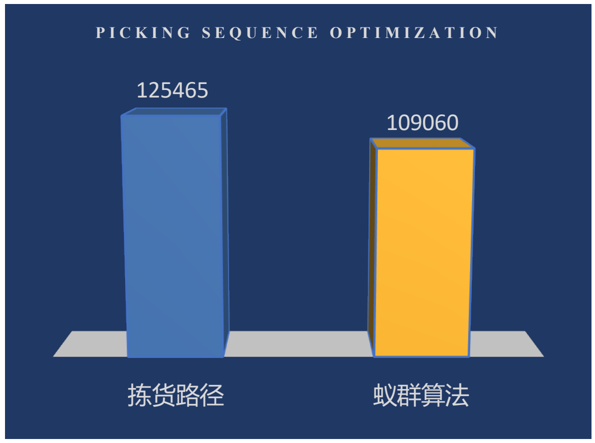
4.4 Effect evaluation

This optimization plan compares the results of the plan through two methods: algorithm optimization and simulation verification. First, there is a lot of optimization space for the optimization of the algorithm. Finally, the simulation verification is also verified, which proves the feasibility of the algorithm. sex.

Through one-to-one simulation modeling, according to the order of the picking path, the total walking path distance is obtained, which saves about 5% of the distance. The comparison of the grouping and single walking distance is shown in the table.



Through one-to-one simulation modeling, the picking path sequence ant colony algorithm recommends the most reasonable sequence comparison, respectively calculates the S-type picking sequence and U-type picking sequence, and obtains the total travel path distance, saving about 13% of the distance. According to The comparison results of algorithms with different picking orders are shown in the table.

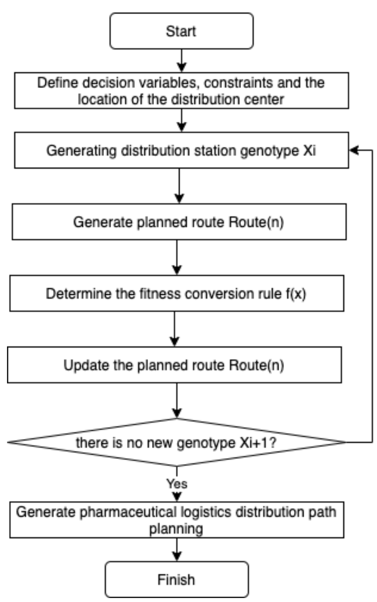


For the picking strategy of pharmaceutical logistics, after optimizing the previously performed S-shaped walking path and the order sorting strategy into a U-shaped walking path and a grouping order sorting strategy, there is indeed a certain amount of walking path and time spent. The degree of optimization can greatly reduce the urgency of medicines, increase the fulfillment rate of orders, and improve the response to orders faster, race against time for the quality of medicines, and reduce the walking path and consumption of pickers Time, save the physical strength of pickers, improve the efficiency of picking drugs, and reduce the loss of drug quality.

5 Distribution design of medical logistics distribution center

5.1 Flowchart of Traveling Salesman Algorithm

First define the decision variables, constraints, and the location of the distribution center, then generate the distribution station genotype, generate the planning path and determine the fitness conversion rule, update the planning path according to the conversion rule, and generate the distribution path if there is no new genotype. Otherwise, the distribution station genotype is regenerated, and the flow chart of the traveling salesman algorithm is shown in the figure.



5.2 Distribution algorithm data

5.2.1 Initial data for distribution route optimization

If route selection is to be made, accurate geographic locations of pharmaceutical companies and distribution centers are required. Because in the path calculation, it is necessary to connect to the actual road network map, which is represented by the latitude and longitude of the location. The specific data is as follows.

In the cost calculation, the freight is defined as the initial value = 50/min, and the vehicle speed is 10m/s.

The latitude and longitude of the two medical distribution centers in Haidian District and Chaoyang District are shown in the table:

Distribution Center	Brief	Latitude	Longitude
Haidian District Distribution Center	HD	40.065716	116.341688
Chaoyang District Distribution Center	CY	39.876608	116.620522

With the help of Baidu map, we first find the optimal path distance between the pharmaceutical company and the pharmaceutical distribution center

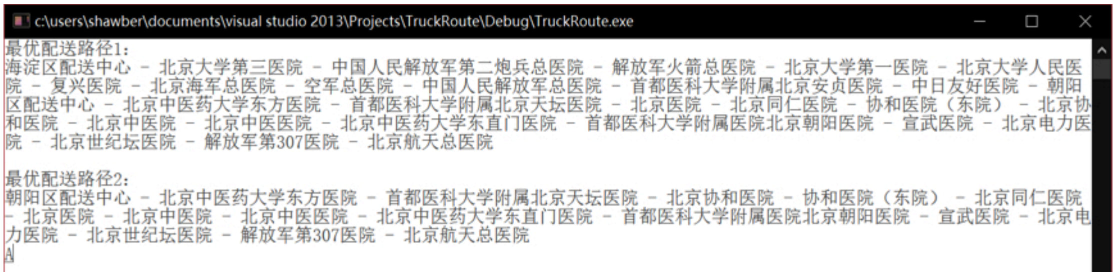
5.2.2 Core algorithm display

In the distribution process, the algorithm design is mainly based on the shortest path as the goal and the medicine urgency as the goal. The core algorithm is shown in the figure.

```
int tsp(int d[][MAX], int n, double e, int l, double at, double t, int s0[])        //定义初始变量
{
int i, j, s[MAX], sum, temp;
sum = INF;
for (i = 0; i < 1000; i++){
        rand_of_n(&s[1], n);
s[0] = 0; s[n + 1] = 0;
temp = 0;
for (j = 0; j <= n; j++)
temp = temp + d[s[j]][s[j + 1]];
if (temp<sum){                                                                       //如果当前是最优解
for (j = 0; j <= n + 1; j++)
s0[j] = s[j];
sum = temp;
}
}
for (i = 0; i < l; i++)
{
int c1, c2;
c1 = random(1, n);                                                                   //启发式随机因子
c2 = random(1, n);
if (c1>c2)
{
int temp = c2; c2 = c1; c1 = temp;
}
if (c1 == c2)
continue;
int df = d[s0[c1 - 1]][s0[c2]] + d[s0[c1]][s0[c2 + 1]] - d[s0[c1 - 1]][s0[c1]] - d[s0[c2]][s0[c2 + 1]];
if (df < 0){
while (c1 < c2){
int temp = s0[c2]; s0[c2] = s0[c1]; s0[c1] = temp;
c1++;
c2--;
}
sum = sum + df;
}
else if (exp(-df / t)>((double)rand() / RAND_MAX)){
while (c1 < c2){
int temp = s0[c2]; s0[c2] = s0[c1]; s0[c1] = temp;
c1++;
c2--;
}
sum = sum + df;
}
t = t * at;
        if (t < e)
break;
}
return sum;
}
```

5.2.3 Algorithm output results

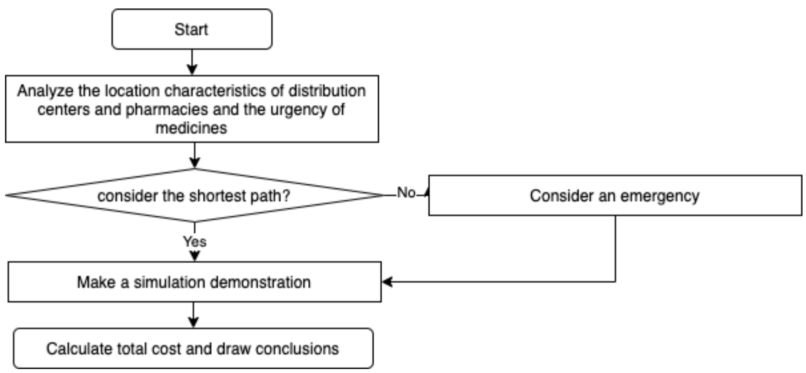
With the help of the heuristic-based traveling salesman algorithm, the conclusions obtained are significantly better than the results of the traditional traveling salesman algorithm, and two delivery plans can be drawn according to their specific routes. The output results of this algorithm are shown in the figure.



5.3 Simulation verification of pharmaceutical logistics distribution based on AnyLogic

5.3.1 Flow chart of medical logistics model

In this medical logistics distribution, we optimized the route from two perspectives. The flowchart is shown in the figure:



One of the solutions is to only consider the shortest route for delivery, requiring trucks to choose the shortest route according to the location of the pharmacy to save freight.

Another option is to take into account the urgent time for delivery. Due to the particularity of certain medicines, it is necessary to give priority to the delivery of the medicine within the specified time, so at this time, the principle of the shortest path must be sacrificed, and the actuality and delivery level of the medicine must be considered for time-priority delivery. Here we define emergency time as a certain pharmacy that needs to receive the delivered medicines within a specified time. If there is a delay in the time, then the delay must be paid.

Based on the analysis of these two distribution perspectives, we found that AnyLogic simulation software can achieve the expected results we want to achieve. It can automatically generate the best route for the delivery of drugs through the location of the distribution center and the pharmacy and can also set an emergency time for a special drug, design a delivery plan based on the emergency time, and finally use the AnyLogic simulation software to analyze the planned route Carrying out real-time demonstration and automatically designing the best plan is extremely beneficial to our logistics and distribution.

5.3.2 Initial data for distribution route optimization

The use of AnyLogic for route optimization requires the accurate geographic location of the distribution center and the delivery place. Because in the path calculation, it is necessary to connect to the actual road network map, which is represented by the latitude and longitude of the location. The specific data is as follows. Here, I chose the delivery destination for one day-each hospital.

In the cost calculation, the freight is defined as the initial value = 50/min, the delay fee is defined as the initial value = 2/min, and the vehicle speed is 10m/s.

The latitude and longitude of the two medical distribution centers in Haidian District and Chaoyang District are shown in the table:

Distribution Center	Brief	Latitude	Longitude
Haidian District Distribution Center	HD	40.065716	116.341688
Chaoyang District Distribution Center	CY	39.876608	116.620522

The latitude and longitude, product category and delivery time of 26 hospitals are shown in the table.

Name	Latitude	Longitude	Product category	Delivery Time
Beijing Tiantan Hospital, Capital Medical University	39.882689	116.410207	2	0
Xuanwu Hospital	39.89866	116.369696	2	0
Chinese People's Liberation Army General Hospital	39.911723	116.283236	1	25
Air Force General Hospital	39.927833	116.307809	1	25
China-Japan Friendship Hospital	39.980342	116.43262	1	25
Union Hospital (Eastern Hospital)	39.918626	116.423937	1	25
The 307th Hospital of the People's Liberation Army	39.867371	116.300875	1	25
Beijing Traditional Chinese Medicine Hospital	39.938089	116.414588	1	50
The Second Artillery General Hospital of the Chinese People's Liberation Army	39.962958	116.378077	1	25
Beijing Anzhen Hospital, Capital Medical University	39.979639	116.40957	2	0
Peking University Third Hospital	39.987928	116.367035	2	0
Beijing University First Hospital	39.938945	116.387426	2	0
Peking University People's Hospital	39.942493	116.360788	2	0
Beijing Union Medical College Hospital	39.918987	116.422316	2	0
Beijing Tongren Hospital	39.909173	116.425794	2	0
Beijing Chaoyang Hospital, Affiliated Hospital of Capital Medical University	39.931589	116.459657	2	0
Beijing Hospital	39.909989	116.421484	2	0
Beijing Traditional Chinese Medicine Hospital	39.93848	116.414487	2	0
Dongzhimen Hospital, Beijing University of Chinese Medicine	39.943141	116.433614	1	25
Beijing Navy General Hospital	39.929051	116.328836	1	50
Beijing Shijitan Hospital	39.90546	116.325247	1	25
Dongfang Hospital, Beijing University of Chinese Medicine	39.870085	116.4388	1	25
Beijing Electric Power Hospital	39.891763	116.322508	2	0
PLA Rocket Army General Hospital	39.962809	116.378824	2	0
Fuxing Hospital	39.911255	116.346587	2	0
Beijing Aerospace General Hospital	39.810509	116.425815	2	0

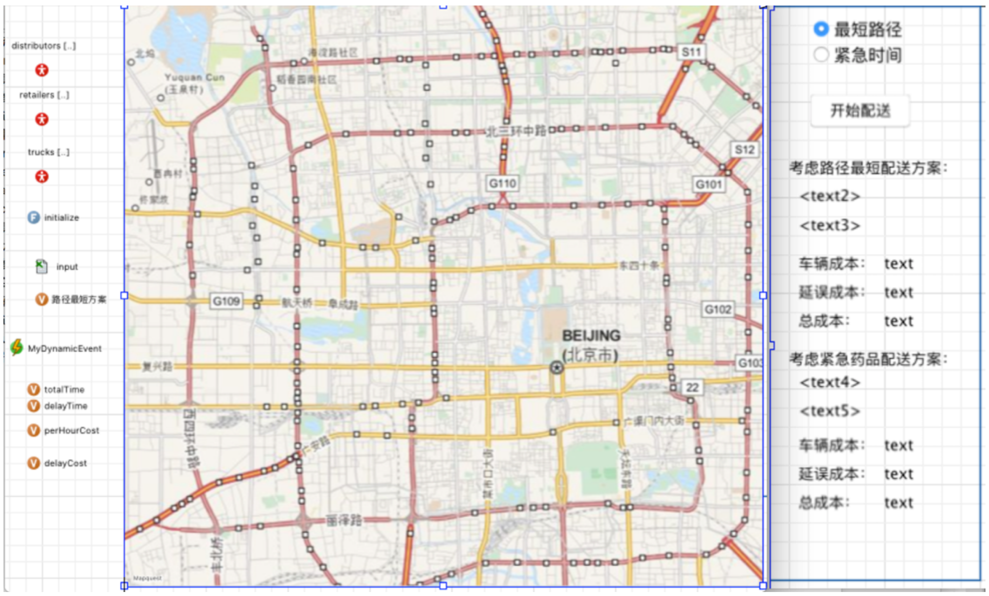
The product category of "1" is the priority delivery emergency medicine, that is, the priority delivery level; the delivery time is the specified delivery time of the emergency medicine.

The delivery time in this table is the time required by the pharmacy and hospital to receive the delivered medicines.

5.3.3 Introduction to the medical logistics model program

5.3.3.1 main-main function

First, we must establish a main function in AnyLogic, which contains all the functions to be used in this simulation-distributors, retailers, trucks, etc. The design of the main function interface is shown in the figure.



The flow chart of the main function is shown in the figure and explained as follows.

(1) Create a new medical distribution center Distributor first, initialize their positions respectively, and then define the latitude and longitude

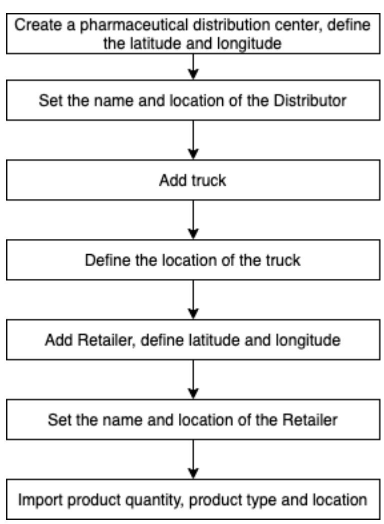
(2) Set the name and location of the Distributor

(3) Add a truck and define the location of the truck

(4) Add a new pharmacy retailer, initialize their positions, and then define the latitude and longitude

(5) Set the name and location of the Retailer

(6) Set product quantity, product type and location.



Such a simple location map is generated.

Here, we use Excel spreadsheets to generate and correlate the latitude and longitude positions of retail stores and distribution centers, and then record the number of orders, product categories, and delayed delivery times for each pharmacy, and use this as a basis for the next program and route process Calculation.

The initialization function (initialize) occupies a leading role in the main function. The main parameters and functions are shown in the table:

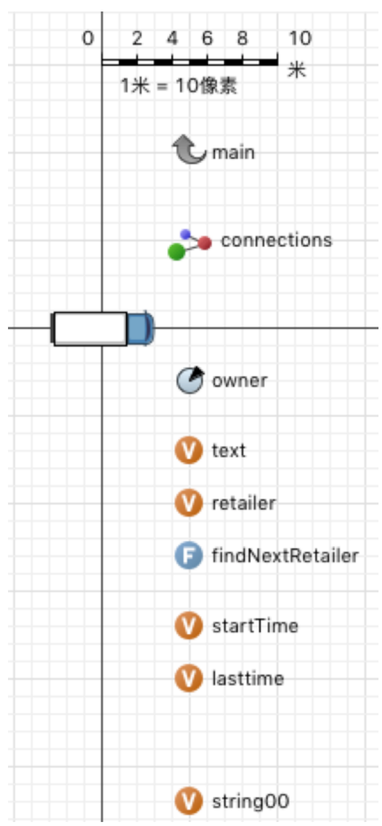
Name	Parameter or function	Meaning
initialize（）	function	Create a text
lat	double type	Initialize the location of the distribution center and then define the longitude
lon	double type	Initialize the location of the distribution center and then define the longitude

The 5 variables defined by this function are shown in the table.

Variable name	Variable Type	Value
Shortest path plan	boolean	/
totalTime	double	/
delayTime	double	/
perHourCost	double	100 / min
delayCost	double	200 / min

5.3.3.2 truck-truck

The category truck still needs to be associated before the main function, and the owner is marked, defined as owner here, and the interface for defining the truck module is shown in the figure.



The category truck still needs to be associated before the main function, and the owner is marked, which is defined as owner here.

The flow chart and explanation of the truck class are as follows (see the flow chart):

(1) Choose the location of a pharmacy

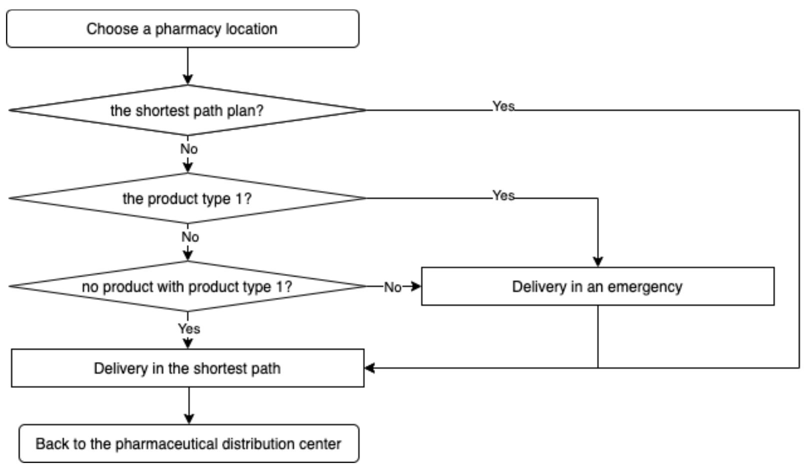
(2) Determine whether the shortest path plan we have selected

(3) If it is, the retail store finds the closest distribution center and adds the collection of retail stores in the distribution center. If the collection is not empty, it will give priority to delivery, and then make a real-time route based on the shortest path plan

(4) If it is not, then judge whether the product type is 1 (that is, a simple judgment must be made about the emergency, and the emergency medicine must be followed by a delivery time, and it must be delivered within this time)

(5) If the product type is 1, find the shortest route for delivery in an emergency, if not, deliver it directly. Among them, it is necessary to ensure that the drug is distributed first and then other drugs are distributed in turn

(6) The plan can be deduced in this way until all delivery is completed.



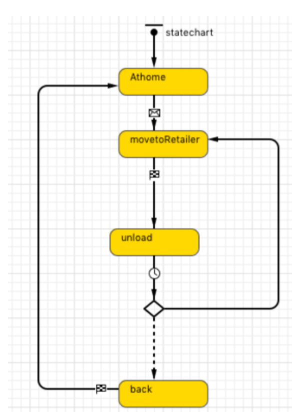
The 1 parameter defined by this function is shown in the table:

Name	Meaning	Type
owner	Truck	Distributor

The 3 variables defined by this function are shown in the table.

Name	Meaning	Type
retailer	pharmacy	Retailer
startTime	When the car is about to depart	double
lastTime	The time it takes for the vehicle to be delivered from the first retail store to the second retail store (just the time on the road)	double

The programming of this topic is mainly to use algorithms to find the next hospital location to be delivered, and the following flow chart is planned, as shown in the figure



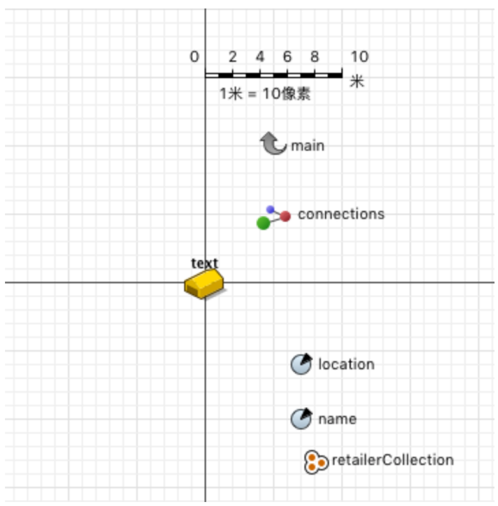
The meaning of the flow chart is shown in the table:

Name	Meaning	Remark
Athome	The car parked at the medical distribution center	After receiving the information, record the delivery time and record it in minutes.
movetoRetailer	Move to various pharmacies	Set up an if statement to judge. First, find the solution with the shortest path. If the path is the shortest, choose this distribution center.
unload	Truck unloading	/
back	The truck returns to the distribution center	End delivery

5.3.3.3 Distributor——Pharmaceutical Distribution Center

Firstly, this interface should be associated with the previously defined main function. The locations of Chaoyang District Distribution Center and Haidian District Distribution Center should be automatically imported from the Excel table, and the images of a warehouse should be used for simulation mark, and the vehicles should be unified from the medical distribution center. At the same time, they set off to distribute the medicines to various pharmacies.

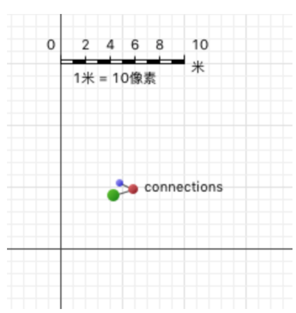
Here, retailerCollection appears as a collection with Retailer, and the module establishment of the medical distribution center is shown in the figure.



5.3.3.4 order——Order

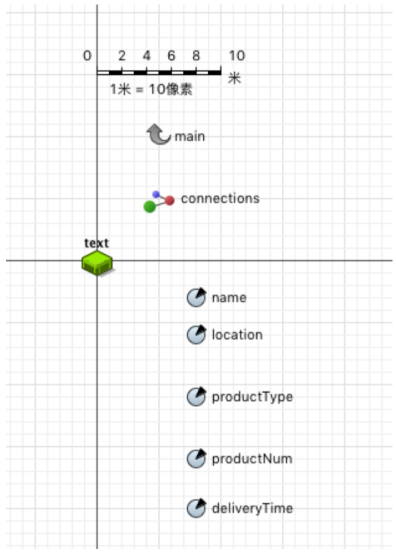
First of all, the order function does not need to be associated with the main function main, so add it to the flowchart.

Secondly, the order serves as an instruction, that is, it starts to run after receiving the order instruction, and then starts to arrange how many medicines are delivered by the vehicle and where the medicines are delivered. The establishment of the order module is shown in the figure.



5.3.3.5 Retailer-Hospital

The Retailer function needs to be associated with the main function main. After the Retailer and the main are associated, when the main receives the order command, the main function starts to run, and completes the information of the above parameters when it reaches the Retailer, and then continues to run. The establishment of the hospital module is shown in the figure.



5.3.3.6 Simulation——simulation experiment

The simulation interface is shown in the figure.

Here is to edit the interface operation of the simulation experiment. The programming of this button is as follows:

(1) For label programming:

```
getState() == IDLE ?
    "运行" :
                                                "最高层智能体"
```

(2) The programming is to define the two words "Run" on this button. (2) The programming is to define the two words "Run" on this button.

```
if ( getState() == IDLE )
    run();
getPresentation().setPresentable( getEngine().getRoot() );
```

The function of the programming is to give this button to the actual meaning of operation, after clicking it, the real operation of the simulation experiment will start.

5.4 Operation results and analysis of AnyLogic model of medical logistics distribution path

5.4.1 AnyLogic model running results

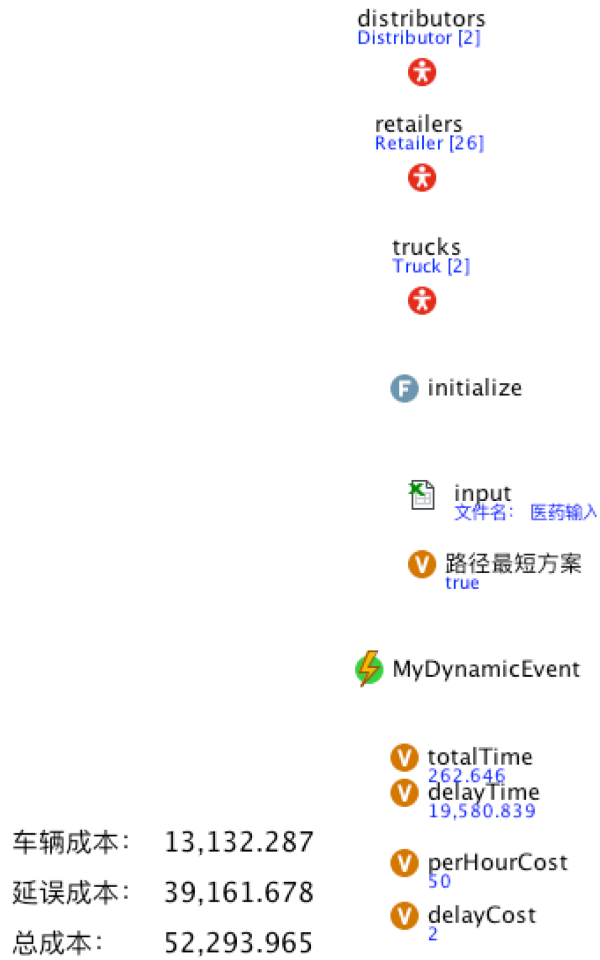
AnyLogic's original technology enables users to quickly create interactive two-dimensional animation simulations in the model editor. Users can connect separate active object graphs with classes of active objects, and put the encapsulated object graph into the container object graph. Assemble these object diagrams when creating the model. In this way, the utilization efficiency of graphics is very high.

Since the result of the software is an animation effect, the starting position and the middle process are intercepted here as a demonstration. The locations of the logistics distribution center, trucks and hospitals in Chaoyang District and Haidian District can be clearly seen from the following two figures.

5.4.2 Analysis of AnyLogic model results

After running the AnyLogic simulation model, the total cost of the two distribution schemes is obtained.

1. Consider the shortest route distribution plan:



Haidian District Distribution Center-Peking University Third Hospital 17.25-PLA Rocket General Hospital 284.82-PLA Second Artillery General Hospital 531.51-Peking University First Hospital 748.76-Peking University People's Hospital 1065.99-Fuxing Hospital 1246.00 -Beijing Naval General Hospital 1502.61-Air Force General Hospital 1580.46-Chinese People's Liberation Army General Hospital 1758.22-Beijing Anzhen Hospital Affiliated to Capital Medical University 2091.32-China-Japan Friendship Hospital 2219.98

Chaoyang District Distribution Center-Oriental Hospital of Beijing University of Traditional Chinese Medicine 19.46-Beijing Tiantan Hospital Affiliated to Capital Medical University 465.29-Beijing Hospital 637.71-Beijing Tongren Hospital 959.57-Peking Union Medical College Hospital 1336.62-Union Hospital (East Hospital) 1546.44- — Beijing Hospital of Traditional Chinese Medicine 1777.54 — Beijing Hospital of Traditional Chinese Medicine 1839.32 — Beijing University of Traditional Chinese Medicine Dongzhimen Hospital 2272.76 — Capital Medical University Affiliated Hospital Beijing Chaoyang Hospital 2402.65 — Xuanwu Hospital 2731.25 — Beijing Electric Power Hospital 3205.57 — Beijing Shijitan Hospital 3292.86 — -The 307th Hospital of the People's Liberation Army 3488.47-Beijing Aerospace General Hospital 3694.72

The total delivery time is 262.646min, and the delay time is 19580.839min.

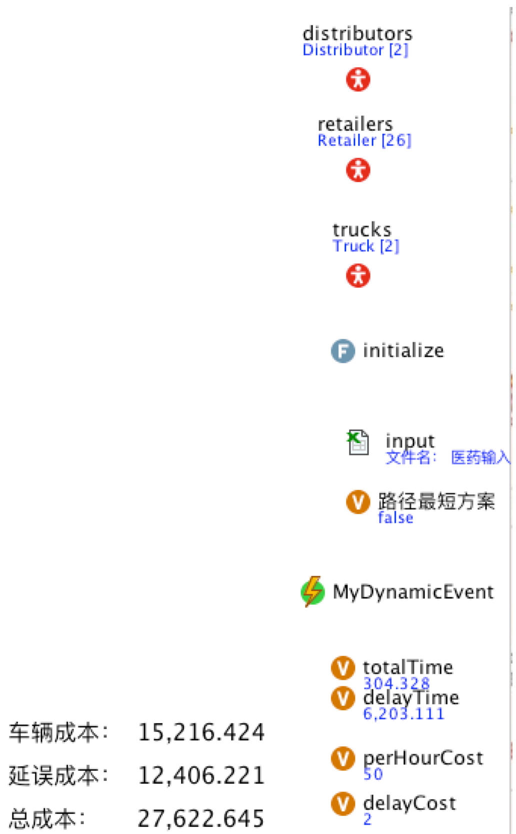
Among them, the total vehicle cost is 13132.287 yuan; the total delay cost is 39161.678 yuan.

The total cost after statistics is 52293.965 yuan.

2. Consider the emergency medicine distribution plan:

Using the AnyLogic method to optimize the network, the first consideration of the logistics network structure is to determine the structure of the product from the pharmaceutical logistics distribution center to the various points. However, the delivery time should also be considered in it, so a comprehensive logistics network optimization must be carried out. .

The time of logistics network optimization design mainly refers to the problem of maintaining product availability in order to meet customer service goals, that is, to maintain a certain level of product availability by shortening the reaction time of production/purchase orders or keeping inventory close to customers Rate.



Haidian District Distribution Center-The Second Artillery General Hospital of the Chinese People's Liberation Army 22.09-China-Japan Friendship Hospital 242.73-Beijing Naval General Hospital 529.50-Air Force General Hospital 607.34-Chinese People's Liberation Army General Hospital 785.10-Fuxing Hospital 1101.55- Peking University People's Hospital 1360.11-Peking University First Hospital 1538.01-PLA Rocket Army General Hospital 1851.19-Peking University Third Hospital 2108.28-Beijing Anzhen Hospital, Capital Medical University 2377.09

Chaoyang District Distribution Center-Beijing University of Traditional Chinese Medicine Dongfang Hospital 19.46-Union Hospital (East Hospital) 468.97-Beijing Traditional Chinese Medicine Hospital 790.07-Beijing University of Traditional Chinese Medicine Dongzhimen Hospital 855.56-Beijing Shijitan Hospital 1001.62-PLA 307 Hospital 1197.22-Beijing Dianli Hospital 1384.94-Xuanwu Hospital 1478.33-Beijing Hospital 1954.27-Beijing Tongren Hospital 2276.14-Peking Union Medical College Hospital 2655.19-Beijing Hospital of Traditional Chinese Medicine 2777.72-Capital Medical University Affiliated Hospital Beijing Chaoyang Hospital 3214.90-Capital Medical Department Beijing Tiantan Hospital Affiliated to the University 3542.19-Beijing Aerospace General Hospital 3721.61

The total delivery time is 304.328min, and the delay time is 6203.111min.

Among them, the total vehicle cost is 15216.424 yuan; the total delay cost is 12406.221 yuan.

The total cost after statistics is 27622.645 yuan.

(3) Summary

Based on the statistics of the above two programs, from the perspective of the total cost of virtual pricing calculation, the path planned with the urgency of the medicine is the optimal path, which greatly reduces the delay cost due to time, which can be used in the process of ensuring the quality and quantity of medicines. The delivery also ensures the timeliness of the delivery of medicines.

Using the distribution routing algorithm established by AnyLogic, after simulation and demonstration, it can provide a variety of distribution routing schemes, and calculate the cost data. It is found that the data is in line with reality and can meet the expectations we require, so the data given by the scheme can still be used. The route is given through the software, the cost is calculated, and the user decides whether to follow the shortest route only or to consider the time requirements. Choose between the two and plan the actual route for the distribution center to achieve the optimization effect.

5.4.3 On the issue of delayed delivery in the model

Compared with the transportation of other items, the delivery of pharmaceutical logistics has a penalty system for delayed delivery is a problem that needs to be considered in its profit. Therefore, in order to avoid this situation, the punishment system is also very strict.

In order to solve the problem of penalties for delayed delivery, we set up a part of the consideration of the delay cost in the model, that is, deliver the goods to the designated place on time, reducing unnecessary losses caused by time delays.

In the process of comparing the two models, we found that from the perspective of the cost of delayed delivery, choosing the shortest time method can reduce the total cost in a relative situation, that is, the shortest time is used when only penalties are considered. The most reasonable way.

6 Conclusion

Through the analysis and optimization of the pharmaceutical logistics distribution center, the following conclusions are mainly drawn:

(1) In the process of site selection, mainly through the hospital's analysis of past drug orders and future predictions, the most suitable distribution center for the hospital is selected

(2) For the shelves and management of medicines, the planning shall be carried out strictly through the special medicine WMS system

(3) In the sorting strategy, the optimization is mainly carried out by the group aggregation strategy of the mileage saving method and the path planning strategy of the ant colony algorithm. The two schemes are optimized by 5% and 13% respectively

(4) In the distribution process, the traveling salesman (TSP) algorithm based on heuristics is mainly used to plan the path of the medicine distribution process, which optimizes nearly 50%.

There are the following innovations in this design:

(1) In the process of site selection, an algorithm based on clustering and ant colony path finding is used to select the location of the pharmaceutical logistics distribution center. Clustering factors are added on the basis of the ant colony algorithm, and the selection process is accurate Higher sex

(2) In the sorting strategy, combining the group collection order strategy and the picking sequence strategy, once again achieves a better optimization effect.

Due to time constraints, there are still some design plans that have not been completed. For example, automation facilities can be added in the sorting process to improve sorting efficiency. This part of the content will be carried out in the later design.

Therefore, this design has played a significant role in the optimization of the pharmaceutical logistics distribution center, and the scheme has certain significance for the real pharmaceutical logistics distribution center.