

# Multi-category Fresh Agricultural Products Are Matched Joint Optimization of Load and Distribution

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**Abstract:** The core of the VRP problem is the process of distribution from the distribution center through multi-demand points under the condition of considering a variety of factors, and the VFP problem, as the precursor to the VRP problem, is that the distribution center carries out reasonable loading and loading according to the needs of multiple demand points. Both are important research topics in the logistics industry. The two influence and restrict each other in the distribution link, and are an indispensable part of the distribution link. This paper combines the two to study the joint optimization problem of VRP problem and VFP problem of urban logistics distribution, which is conducive to the effective integration of logistics and transportation resources. In this study, multi-category fresh agricultural products are taken as the research object, and the joint optimization of three-dimensional loading and distribution routes of multi-category fresh agricultural products at multiple task demand points in a distribution center is studied. In the process of joint optimization, the fragile characteristics of some products and the different sizes of each product feature are considered, and a three-dimensional loading-distribution route joint optimization model is established. In the process of joint optimization of stowage and distribution, the fragile characteristics of some products and the different sizes of each product feature are considered, and a three-dimensional joint optimization model of stowage and distribution route is established. The multi-objective problem with the largest load rate and the smallest mileage is converted into a single-objective function with the lowest cost; Secondly, the application of GA-TS hybrid algorithm to joint optimization is proposed. Finally, a study simulation is performed. The distribution scheme and loading scheme affect the size of the loading rate and the number of miles delivered. Distribution centers have found that proper stacking can effectively ensure vehicle load rates while reducing operating costs.

**Keywords:** Three-dimensional loading, Vehicle route optimization, Joint optimization of stowage and distribution, Fresh produce, GA-TS.

## 1. Introduction

With the gradual development of logistics technology in the logistics industry, it has become an important factor affecting the core competitiveness of enterprises. Goods for multiple categories of fresh produce are currently more expensive than logistics expenditures, and customer satisfaction is lower due to poor connection. How to effectively reduce the transportation cost of fresh goods and improve the service quality of logistics is an important research topic in the current logistics management process

China is the largest consumer of fresh agricultural products. Statistics in 2021 can observe that the import volume of grain, meat and other agricultural products increased by 28% and 60.4% respectively, which shows that China's demand for fresh agricultural products is urgent. However, relevant data show that 80%~90% of fruits and vegetables, meat and aquatic products in the United States and Japan are cold chain transportation, while the domestic cold chain transportation rate is only 15%, 30% and 40%; The proportion of domestic cold chain process broken chain is as high as 67%, 50% and 42%, which is much higher than the proportion of cold chain broken chain in developed countries. Therefore, the distribution of cold chain logistics in China is not optimistic, and there is a lack of scientific planning methods and systematic analysis. Therefore, the distribution issue is very important in the logistics and transportation of fresh produce. At this stage, due to the different demand points for products, and the time window is more scattered, the complexity of cargo transportation is increased, resulting in empty load and high transportation costs in the transportation process. The

final stage of the transport of fresh produce is urban transport. The main goal of such orientation is to reduce the UFT actual impacts on mobility and delivery efficiency [1,2]

According to the findings of a survey on urban logistics, conducted by [3], solving the Vehicle Routing Problem (VRP). Substantial quantities of agri-fresh produce especially fruits and vegetables are lost and wasted at various channels and operational levels in the agri-fresh produce supply chain. The empirical study evaluates sixteen key factors. The result is a lack of coordination between production, processing, fresh markets and inadequate logistics and so on by [4].

Based on these facts, we investigated a variant of the combined routing and loading problem applied to fresh produce, which is known as the CVRP with three-dimensional loading constraints (3L-CVRP).

How to better distribute has also become a problem in the logistics industry. In modern logistics, distribution is a combination of "distribution" and "delivery", "distribution" refers to how to carry out the loading of goods, "delivery" refers to how to send to each demand point through path planning, the two are equally important, in the distribution process of multi-product orders, the loading process of fresh agricultural products into "cargo loading", the distribution vehicle of the product from the distribution center to each demand point of the process into "path planning", and due to the demand point of each demand point product quantity, volume, weight, etc. are different, and considering the urgency of customer needs, the concept of time windows was introduced in order to achieve the purpose of truly improving the distribution system and efficiency.

The relationship between the distribution route problem and the cargo stowage problem is quite close, and the vehicle routing scheme affects whether the cargo loading scheme is effective, while the cargo stowage scheme determines the efficiency of the vehicle route arrangement, and the correlation between the two has a direct impact on the cost of distribution and the level of service. Vehicle path planning is optimal, but cargo stowage is not necessarily optimal, how to combine the "distribution" and "delivery" of logistics more efficiently is the optimal logistics distribution service system. Reasonable assembly is carried out according to the different needs of each demand point. The characteristics of fresh agricultural products are designed to match the loading with the reasonable utilization volume and load, and the path of the vehicle is optimized according to the loading sequence and loading scheme.

Based on the above background, combining the vehicle routing problem and the packing problem of multi-category fresh agricultural products can then improve the vehicle space rate and combine the distribution route optimization. Ensure that on the basis of completing the distribution task, the logistics cost is further reduced, the distribution efficiency is improved, and customer satisfaction is improved. The combination of "distribution" and "delivery" of logistics with higher efficiency and quality will effectively reduce logistics expenses and improve the income of logistics companies.

**Table 1.** Three Scheme comparing

Number	Scheme 1	Scheme 2	Scheme 3
1	456	456	123
2	789	213	644
3	213	654	649

## 2. Literature References

In practice, many optimization problems are NP-hard, and solving them requires a significant amount of computational work.

When solving NP-hard problems, exact methods are often ineffective in practice because they are time-consuming once they deal with real-world instances. In fact, the time required to solve a particular problem instance rises in a super-polynomial pattern as the size of the instance grows, making exact methods impractical [6]. For this reason, a multitude of meta-heuristics approaches have been developed.

The vehicle routing problem has several variants [6]. It most common studied ones in urban freight distribution are the CVRP, VRP with time windows (VRPTW) and clustered VRP [7-9]. In this paper, we study the CVRP in the transportation of fresh produce.

### 2.1. Fresh produce logistics

At present, the logistics and distribution problems of fresh produce are mostly an extension of the VRP problem, and Ana Osvald[10] first proposed the necessity of vehicle path planning for fresh produce in 2008, taking its perishable characteristics as part of the total distribution cost, and using the heuristic method of taboo search to solve the problem. On this basis, many scholars have developed this problem. On the one hand, some scholars have found that the time window is very important for the distribution of fresh agricultural products, so they integrate the delivery time window into the distribution route problem. Xuping Wang [11] proposes the

multi-target vehicle path problem with a time window. Anil [12] added a hard time window constraint, specified the minimum quality level of fresh produce, established a mixed integer nonlinear programming problem, and solved the problem of vehicle path optimization of fresh produce.

On the other hand, some scholars have studied the entire chain of fresh agricultural products and found that the problem of packing and path planning are very important for the logistics of fresh agricultural products. Santosh Anand [13] considered what are the key factors for the loss and waste of fresh agricultural products in the supply chain, understood from multiple channels, and processed the factors of multiple influencing factors, and found that the lack of coordination between production, processing and fresh markets, transportation vehicle problems, and logistics and distribution problems greatly affected the profit and loss of fresh agricultural products. Yajun Zhan[14] studies last-mile retail order allocation problems, which combine time coupling, order allocation, and vehicle scheduling. A split-order packaging decision was proposed to integrate different types of fresh produce. Aijun Liu [15] et al. reasonably planned the entire chain of fresh agricultural products, established a vehicle route optimization model according to the actual location-inventory-path, and realized the unified upstream and downstream scheduling and planning of vehicle routes. Liying Song [16] builds on Aijun Liu to consider the impact of whether suppliers are allowed to ship directly to retailers, sets capacity constraints, and continues to delve into the problem of vehicle routing for fresh produce based on the chain.

### 2.2. Bin packing problem

The problem of cargo packing originally began in the United States, and as more and more scholars solve related problems from different dimensions, there are one-dimensional packing problems, two-dimensional plane packing problems, and three-dimensional three-dimensional packing problems. At present, the main problem of loading is three-dimensional boxing. Among the many elements, the two most common and extensive elements are: geometric size and bulk density ratio, when different weights of goods are matched with each other to load vehicles, the volume and load of the distribution vehicle are greatly used to improve the vehicle loading rate.

One-dimensional boxing problems are: Claudio Arbib [17] solves that the length of a part affects the box in which it is placed, so an accurate ILP formula and heuristic are set up to solve the one-dimensional bin packaging problem, with the goal of minimizing the number of boxes and the maximum application of the part. Xavier Schepler [18] et al. 1D items of different sizes are assigned to a minimum number of identical 1D boxes to minimize the number of boxes used. The capacity of each box cannot be exceeded. Some variations have been made to deal with this issue to account for cases where there are items of uncertain size.

The two-dimensional boxing problem is more in-depth research, such as: LijunWei [19] et al. are studying the two-dimensional boxing problem again, and their task is to pack all given rectangles into boxes of various sizes in order to minimize the total area of the boxes used, divide the search space of two-dimensional variable-size boxes into sets and impose order on the sets, and then use a goal-driven approach to take advantage of the special structure of this partitioning

solution space. Nadia Dahmani [20] et al. proposed the variable neighborhood descent method based on the two-dimensional packing problem, Yu Ping et al. established a stowage model aimed at maximizing the total order volume, minimizing the total number of trips, and minimizing the total number of cargo loading and unloading for the multi-objective cargo loading problem, and proposed a multi-objective genetic algorithm based on elite strategy with rapid convergence.

Due to the in-depth research, the main research direction has changed from the two-dimensional boxing problem of the plane to the three-dimensional boxing problem. Early Leonardo Junqueira [20] and others found that the stability and bearing strength of the horizontal line of goods were not considered in the three-dimensional packing problems from rectangular box loading to container pallet, so they established a three-dimensional packing model to take it into account. Alessio Trivella [21] proposed a MIP model to extend the three-dimensional loading problem considering its load balancing state for the multi-dimensional packing problem. Based on the three-dimensional packing problem, Célia Paquay [22] et al. extended it to air cargo, setting up a three-dimensional packing model that can be applied to aircraft. Fatma Gzara [23] considers the packing problem of pallets on the basis of the packing problem, and incorporates the load-bearing and support problems into the model, which enriches the three-dimensional packing problem. Fanchao Meng [24] et al. proposed the quadratic multi-constrained variable-size boxing problem against the background of three-dimensional three-dimensional boxing, and involved a VNS algorithm to solve the problem.

### **2.3. Vehicle routing problems with loading constraints**

Ricardo Fukasawa [25] proposed a set division formula for taking into account the vehicle capacity limitation in consideration of the random demand vehicle path problem. Van Son Nguyen [26] proposed a neighborhood search algorithm to solve the problem of vehicle distribution in multi-trip and multi-distribution centers considering its capacity constraints. Carise E [27] expanded the multi-distribution center vehicle routing problem to take into account real-world routing over time as well as capacity constraints. The 3L-CVRP has been studied intensively in the

recent years so that the results for this benchmark have been improved repeatedly by researchers (e.g. Tarantilis et al. [28], Fuellerer et al. [29], Bortfeldt (2012) and Wei et al. [30])

### **2.4. Combined Vehicle Routing and Container Loading Problem**

The comprehensive optimization of cargo stowage and distribution route was first proposed by Badeau, who proposed to use ant colony algorithm to solve the joint optimization problem of two-dimensional cargo loading and vehicle path, comprehensively considering its correlation, and made an overall optimization of its process.

Recent studies on 2D loading problems such as: Xiangyi Zhang [31] et al. developed a score cutting algorithm to study the vehicle path planning problem with two-dimensional load constraint. Bin Ji [32] et al. proposed the problem of heterogeneous vehicle routing from customer direct to customer cross-docking and two-dimensional stowage constraints.

In the early days, Guenther Fuellerer [33] et al. found that the problem of vehicle path optimization under three-dimensional loading constraints is very practical, but there are few people studying and there are no examples. Therefore, this problem was rectified in order to improve the service for customers at the lowest cost, and an ant colony algorithm was designed to solve the problem.

Part of the study is the problem of distribution route planning based on loading constraints. Youssef Meliani [34] et al. studied the special integration of vehicle distribution with three-dimensional loading constraints, and proposed for the first time a fitting decreasing heuristic, considering the rectangular items to be delivered to the customer and the loading constraints to be satisfied. Andreas Bortfeldt [35] et al. solve the problem of vehicle routing with three-dimensional loading constraints, deliver their packages to the demand point multiple times as a variant, and design a hybrid algorithm to solve the problem. Yong Wang [36] et al. proposed a resource sharing scheme based on customer clustering to improve vehicle loading rate based on characteristics such as cargo type and size for the multi-vehicle route problem considering time window and three-dimensional loading constraints.

A part of the research on how to better solve the packing problem under the premise of path optimization. Mustafa Küçük [37] et al. proposed a solution method for the three-dimensional loading capacity vehicle route problem consisting of vehicle path and three-dimensional loading problem in distribution logistics based on constraint programming, aiming at the small size problem. Ahmad Baubaid [38] found that current LTL carriers consolidate cargo from the terminal and transport it to the destination, with the day's transport dynamics determining the freight route. Therefore, the problem is modeled as MDP and the ADP solution is introduced to solve the dynamic routing problem of LTL transportation considering two-dimensional packing. Okan Örsan Özener [39] found that the current trucking enterprises are not sensitive to the perception of volume, which is fine for truckload transportation customers, but for LTL transportation customers, how to use trucks to make their overall utilization increase while shortest routing, so they designed corresponding algorithms to solve the routing problem of trucks.

## **3. Problem Formulation**

The setting considers the actual relationship between cargo stowage and vehicle routing during the distribution of multi-category fresh agricultural products, determines the idea of comprehensive optimization, selects two models and uses them to integrate cargo stowage and vehicle route models, establishes a comprehensive model through the integration of relevant parameters and variables and the combination of constraints and targets, introduces actual cost analysis, transforms multi-objective problems into single-objective problems, and solves the model. Due to the characteristics of many and miscellaneous orders for fresh agricultural products that can be mixed in multiple categories, some products may be affected by loading factors and may cause deterioration, damage and other behaviors. Therefore, when establishing the model, it will be necessary to consider the stacking of vulnerable products into constraints, and it needs to be reasonably boxed and transported. The model of cargo stowage problem has different models for different problems,

the product object considered in this article is multi-category orders and is a single distribution center of goods, and because it is a distribution center departure problem at the same time, so do not consider the packing of the already existing cargo stowage form and on this basis of the problem of stowing, at this time the box is empty state, this article will choose this classic cargo stowage model for consolidation.

The three-dimensional coordinate system is set up at the origin of the lower vertex on the left front side of the split truck car near the driver, and the three-dimensional diagram method of the box coordinate system is shown in Figure 1

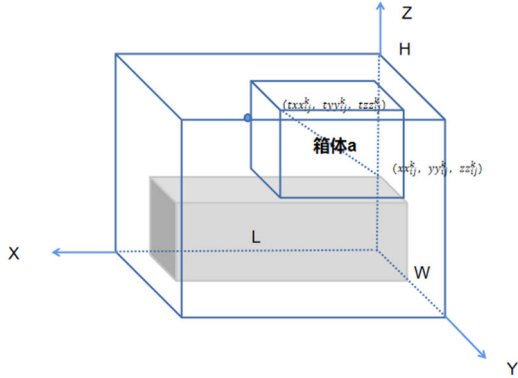


Figure 1. 3D coordinate system.

The application of multi-category fresh agricultural product stowage and vehicle distribution model is described as follows: According to the background setting of this paper, the comprehensive optimization model mainly studied in this chapter is the distribution of multiple vehicles of the same model to multiple demand points in a single distribution center without considering the complexity of the road network. The location of each demand point is known, the distance between demand points is known, and the rated length, width, height, rated volume and rated load capacity of the carriage are known. Under the premise of satisfying constraints, the space in the carriage is better utilized to achieve the goal of the minimum number of vehicles used and the shortest total mileage of all delivery vehicles. The layout diagram of the comprehensive optimization is shown in Figure 2.

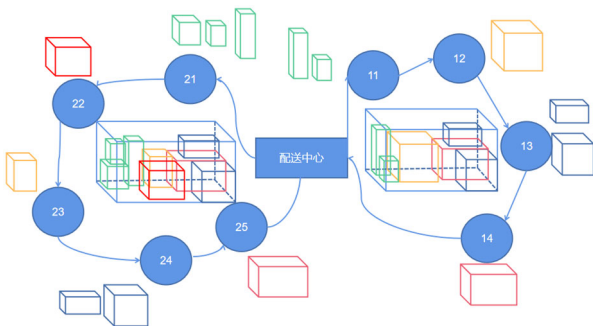


Figure 2. 3L-CVRP example

Based on the notations used in the literature, the problem is defined as a graph  $G = \{A, E\}$  where  $A$  is the vertex set containing  $n$  customers and the depot (vertex 0), and  $E = \{(i, j): i, j \in V; i \neq j\}$  is the set of edges (arcs). A fleet of  $m$  heterogeneous vehicles is located at the depot. Each vehicle  $k$  has a maximum weight capacity  $G$ , cost  $C$  and a threedimensional loading space of length  $L$ , width  $W$  and height  $H$ , such that  $V = L * H * W$ . The cost of moving the vehicle  $k = (1, \dots, m)$  from  $i$  to  $j$  is given by

$c_2 \sum_{k=1}^m \sum_{i=0}^n \sum_{j=0}^n x_{ij}^k * d_{ij}$  such that  $d_{ij}$  is the distance between the customer  $i$  and  $j$ . The demand of each client  $i = (1, \dots, n)$  is expressed in terms of a set of three-dimensional items.

$x_{ij}^k$ : If vehicle  $k$  goes from demand point  $i$  to demand point  $j$ , the decision variable =1, otherwise it is 0

$y_k$ : equal to 1 if the vehicle  $k$  is used, 0 otherwise

$s_{ik}$ : If the delivery vehicle  $K$  is loaded with a product at demand point  $I$ , the decision variable =1, otherwise it is 0

In this study, we consider the following assumptions:

- The fleet is the same model
- The fleet size is unlimited;
- Items are rectangular boxes;
- Two out of six possible orientations are allowed;
- The loading and unloading is possible only form the rear of the vehicle.

A route must meet the following routing constraints and For the 3L-CVRP, the following loading constraints must be additionally respected:

(C1) This document considers the CVRP problem. The distribution route is a closed route (Eq(2), Eq(3))

(C2) Due to background restrictions, the product specifications are small batch goods, so there is no splitting process, and each customer only visits once. (Eq(4))

(C3) If a vehicle arrives to a node  $i \in n$ , then it must depart from this node to another one. (Eq(5))

(C4) The total weight capacity and volume of the items in each vehicle must not exceed the load capacity and volume of the vehicle, (Eq(8)) (Eq(9))

(C5) Items loaded into a vehicle must not overlap. (Non-overlapping constraint) (Eq(10))

(C6) Each product box is parallel to the X-, Y-and Z-axis. And the position of the items in the carriage can be placed at will. (Eq(7))

(C7) An item placed in a vehicle must be completely inside the loading space. In other words, its edges should not extend beyond those of the vehicle. (Containing constraint) (Eq(6))

(C8) Due to the characteristics of fresh produce, this constraint is specialized. Non-fragile items (of index  $f = 0$ ) cannot be stacked on the surface of fragile items (fragility constraint). However, two fragile lots can be placed one above the other(Eq(11))

(C9) The different categories of products required for each demand point will be loaded in full containers, and the specific specifications will be cuboids or cubes with regular length, width and height, regardless of special shapes

(C10)LIFO constraint: First down and then up(Eq(12))

Both the objective function and the constraints of the 3L-CVRP model are mathematically formulated as shown in (1) and (2)–(15), respectively:

$$\text{Min}C = c_1 \sum_{k=1}^m y_k + c_2 \sum_{k=1}^m \sum_{i=0}^n \sum_{j=0}^n x_{ij}^k * d_{ij} \quad (1)$$

$$\sum_{k=1}^m \sum_{j=1}^n x_{0j}^k = m \quad (2)$$

$$\sum_{k=1}^m \sum_{i=1}^n x_{i0}^k = m \quad (3)$$

$$\sum_{i=0}^n \sum_{j=0}^n \sum_{k=1}^m x_{ij}^k = 1 \quad (4)$$

$$\sum_{k=1}^m \sum_{\substack{i=1 \\ i \neq h}}^n x_{ih}^k - \sum_{k=1}^m \sum_{\substack{j=1 \\ j \neq h}}^n x_{hj}^k = 0 \quad (5)$$

$$\begin{cases} txx_{ip}^k \leq L \\ tyy_{ip}^k \leq W \\ tzz_{ip}^k \leq Z \end{cases} \quad (6)$$

$i = 1, 2, \dots, n, \quad p = 1, 2, \dots, m, \quad k = 1, 2, \dots, m$

$$\begin{aligned} txx_{ip}^k &= xx_{ip}^k + \Psi x(l_{ip}, w_{ip}, z_{ip}, dir) \\ tyy_{ip}^k &= yy_{ip}^k + \Psi y(l_{ip}, w_{ip}, z_{ip}, dir) \\ tzz_{ip}^k &= zz_{ip}^k + \Psi z(l_{ip}, w_{ip}, z_{ip}, dir) \end{aligned} \quad (7)$$

$$\sum_{i=1}^n \sum_{k=1}^m x_{ip}^k g_{ip} \leq y_k G \quad (8)$$

$$\sum_{i=1}^n \sum_{k=1}^m s_{ip}^k v_{ip} \leq y_k V \quad (9)$$

$$\begin{cases} xx_{ip}^k \geq txx_{ip}^k, \forall xx_{ip}^k \geq txx_{ip}^k \\ yy_{ip}^k \geq tyy_{ip}^k, \forall yy_{ip}^k \geq tyy_{ip}^k \\ zz_{ip}^k \geq tzz_{ip}^k, \forall zz_{ip}^k \geq tzz_{ip}^k \end{cases} \quad (10)$$

$$zz_{ip}^k * f_{ip} \leq zz_{ip}^k * f_{ip} \quad (11)$$

$$\min\{zz_{ip}^k\} s_{ip}^k \geq \max\{txx_{ip}^k\} s_{ip}^k \quad (12)$$

$$x_{ij}^k = \{0,1\} \quad (13)$$

$$s_{ik} = \{0,1\} \quad (14)$$

$$y_{jk} = \{0,1\} \quad (15)$$

## 4. Problem Solving Methodology

Since integrated routing problems, such as 3L-CVRP, combine optimization problems that are generally NP-hard, metaheuristic approaches are the most suitable to be

considered as resolution approaches. Therefore, the proposed approach, in this work, is based on metaheuristics, namely GA-TS

Each part of the 3L-CVRP is treated separately following the rule ‘‘Routing first, Packing second’’. The proposed approach is different from the existing studies related to 3L-CVRP in four aspects:

(1) Unlike the traditional GA algorithm and TS algorithm, GA-TS algorithm mixes the advantages of both. A robust two-phase algorithm with new procedures.

(2) A packing heuristic that make use of the concept of levels

(3) A Local Search procedure enhanced with the concept of Tabu list is proposed to generate different loading sequences.

(4) A memory is introduced in order to speed up the search Process

For a given route, the algorithm tries to determine whether all the items ordered by the customers can be loaded into the considered vehicle. The loading feasibility is examined in terms of the constraints defined in Section 3. If the algorithm fails to produce any feasible loading, the route is considered as unfeasible. More precisely, its starts by generating an order sequence of all the customers covered by the examined route. The order sequence is initially constructed according to the following sorting rules:

(1) If the LIFO constraint is considered, the items are listed in reverse visiting order of the corresponding customer, so that the unloading will be direct without any repositioning. Break ties using the phase (2)

(2) If fragility constraint is considered, the items are sorted so that fragile items comes after non-fragile items. Because nonfragile boxes cannot be placed on top of

fragile box. Break ties using the phase (3)

(3) Sort the items by decreasing order of height and in some executions length, while respecting the previous rules.

GA-TS algorithm fitness: In this paper, the optimization goal is to minimize logistics operating costs and maximize the loading rate of distribution vehicles, and the multi-objective is transformed into a single goal, and the fitness function of the designed genetic algorithm is shown in Equation (16).

$$f(x) = \frac{1}{C} \quad (16)$$

Tabu List and Tabu Length: A tabu list is a loop designed for taboo objects. The main purpose of list recording is to prevent the algorithm from following in the process of searching. Ring, to avoid falling into local optimum. The length of the Tabu is not considered to be defiant. In the case of guidelines, taboo objects are not allowed to be selected for the maximum overlap. The number of generations, taboo length The selection of TL can be done in a variety of ways, for example. TL = Constant.

Secondly, a relaxed TS heuristic is applied on the initial solution in order to produce better solutions. It explores the search space by performing moves on the current solution so new regions are explored.

## 5. Computational Study

### 5.1. Parameters settings

In order to verify the feasibility of the model and the effectiveness of the optimization algorithm, this part will select a fresh fruit wholesale store in Shanghai as an example to verify the model and algorithm. There are 15 main items distributed in this distribution center, of which the length, width, height and weight are not afraid of extrusion are shown in the table 1 below. Non-fragile=1, fragile=0

**Table 1.** Various types of cargo specifications

Number	Bear pressure	length	wide	high	weight
1	1	900	600	450	12.5kg
2	1	600	600	300	10kg
3	1	600	300	300	7.5kg
4	1	450	300	300	5kg
5	0	450	300	300	5kg
6	0	450	300	150	2.5kg

The distribution uses the same model of 4.2 meters light van fuel vehicle for distribution, because the model for refrigerated trucks need refrigerated transportation, so the fuel consumption per 100 kilometers exceeds the non-refrigerated compartment cargo transporter, about 20L, the relevant parameter information of this vehicle is shown in Table 2 below, for the convenience of calculation so take an approximate integer value.

**Table 2.** Tables of relevant dimensional parameters for the vehicle

Rated load	Length (mm)	Wide (mm)	High (mm)	Fuel consumption per 100 km
1500kg	4000	2000	2000	20L

To establish the relevant joint optimization model, the relevant costs need to be calculated and fixed parameter settings. For details of the relevant parameters, see Table 3-5 Cost and Fixed Parameters. The fixed cost of the vehicle includes the purchase fee, insurance fee, etc., and the sum of the expenses is roughly about 120,000. Driver fees, single vehicle dispatch fees, and discount fees are all set as the cost per time for using the vehicle. The variable cost of the vehicle in this article only considers the fuel cost, according to the average price of 1L of fuel in the month is about 7.5 yuan, and the fuel consumption is 20L per 100 kilometers, which can be calculated as about 1.5 yuan per kilometer. The fuel tank has

a limited fuel storage of 130 liters, and it can be estimated that the total mileage of the van from the distribution center and finally back to the distribution center without load should not exceed 650 kilometers based on the fuel consumption of 20 liters per 100 kilometers.

**Table 3.** Cost and related fixed parameters

Parameter	Unit	value
Single fixed cost $C_1$	Yuan	300
variable cost $C_2$	Yuan/km	1.5

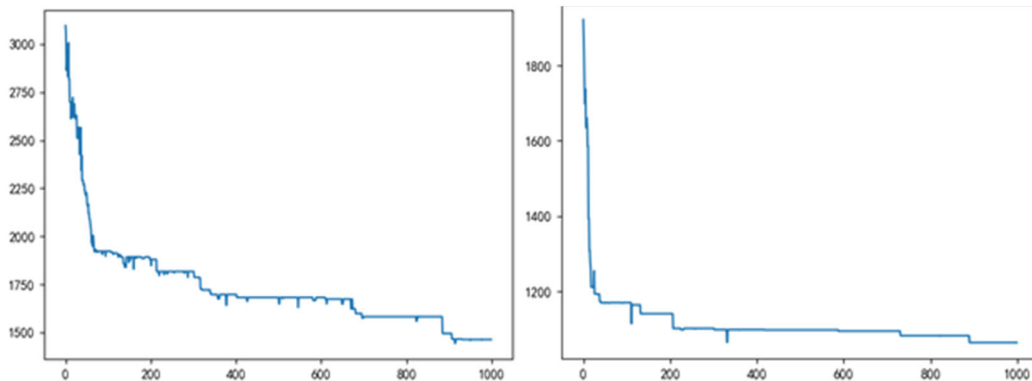
By using the algorithm written in Python to test the model and the algorithms involved, the validity of the model and the practicality of the algorithm are shown in turn. For the improvement of the genetic algorithm for solving, changing the four parameters of the algorithm, such as population size, number of iterations, mutation probability, and cross probability, has an impact on the solution of the problem, and at present, more scholars set the problem to the following four sets of parameters for solving, and different parameters are set for comparative analysis, and the parameter settings are shown in Table 4

**Table 4.** The parameter takes a value

	Popsiz	$P_c$	$P_m$	gen
1	50	0.8	0.005	500
2	100	0.9	0.01	800
3	150	0.7	0.015	1000
4	200	0.8	0.02	1000

The values of each set of parameters were calculated 20 times independently, and through comparative analysis, it was found that the effect was better when the population size was 200, the gen= 1000, the  $P_m=0.02$ , and the  $P_c=0.8$ .

After writing the code using Python, the optimal distribution route and the loading rate of each vehicle and the total delivery cost in the estimated budget are obtained after 800 iterations. The iteration diagram is shown in Figure 3, and the final vehicle distribution route is shown in Figure 4. Combined with the demand for different goods at each demand point on each distribution route, the loading scheme is generated by loading in reverse order according to its visit order, and it can be seen from the loading rate calculation result that the packing result should meet the loading constraints



**Figure 3** Iteration chart comparison

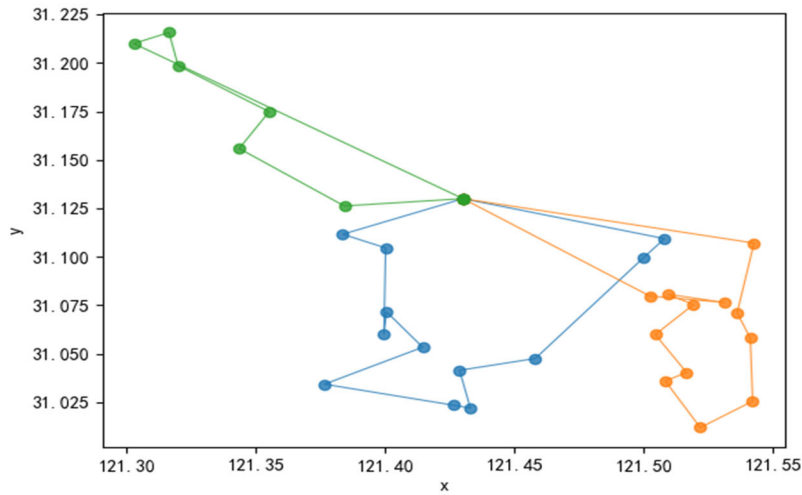


Figure 4 Vehicle delivery roadmap

Table 5 shows the distribution plan before optimization. According to the operation results, the reasonable transportation arrangement scheme is optimized, as shown in Table 6.

Table 5. Optimize pre-distribution routes and load rates

Delivery vehicles	route	Load rates
1	DC→4→24→17→10 →11→9→8→DC	57.5%
2	DC→12→21→30→22→ 15→25→16→29→DC	62.7 %
3	DC→27→2→1→3→5→6→7→ DC	50.8%
4	DC→13→18→26→28→14→19 →20→23→ DC	59.8%

Table 6. Optimized distribution routes and load rates

Delivery vehicles	route	Load rates
1	DC→7→8→10→9→11→17→24 →4→12→21→16→29→DC	89.7%
2	DC→25→14→15→26→ 23→19→20→30→22→18→13→ 28→DC	90.5 %
3	DC→2→1→3→27→5→6→ DC	50.6%

Optimize the entire distribution network with the goal of shortest total distribution routes and the fewest number of vehicles (i.e., maximizing the average load rate of vehicles). As can be seen from Table 7, the optimized distribution plan requires 3 vehicles to deliver 30 demand points. The comparison before and after the optimization of the 3D loading distribution scheme shows the total delivery distance, distribution cost, average loading rate, and so on.

Table 7. Fulfillment scenario cost

scheme	Number of vehicles used	Total distance delivered (km)	Distribution cost	Average load rate
1	4	172.788	1459.17	57.7%
2	3	181.824	1172.74	76.93%

As can be seen from Table 7 after optimizing the distribution plan after applying the GA-TS hybrid algorithm, it can be seen that although the sum of the loading rates has not changed, the average loading rate has changed from 57.7% to 76.93% now, and the average loading rate has increased by 19.23%. The three indicators with the greatest impact on the total cost were selected respectively, and the total transportation distance, total transportation cost and number of vehicles were compared, and the comparison chart was shown in Figure 5. Only the minimum total transport distance is considered before optimization. Departing from the distribution center at the same time, the total distance of the distribution is small, but due to the low average load rate, more delivery vehicles are required for transportation. At the same time, after considering the optimization of the two, the loading rate is greatly improved, the number of vehicles used, and the total transportation cost is effectively saved.

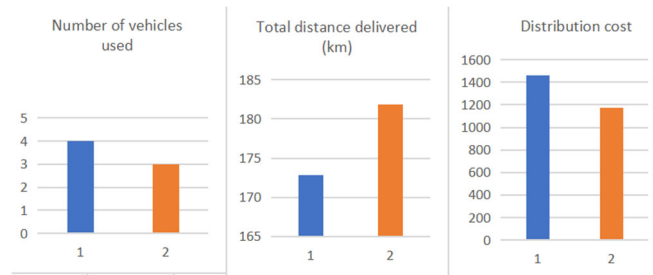


Figure 5. Optimize before and after charts

From Figure 6, analyzing the data of vehicle 2 and vehicle 3, it can be seen that vehicle 3 on the basis of vehicle 1 and vehicle 2 to increase the loading rate as much as possible, vehicle 3 loading rate is smaller than the previous two vehicles, if new demand points or demand products are added, the loading rate of vehicle 3 will increase, which will reduce the total number of delivery vehicles. The total number of cartons of vehicle 2 is 168, the total number of 2.5kg products is 32, accounting for 19.05%, the total number of 5kg products is 39, accounting for 23.21%, the total number of 7.5kg products is 10, accounting for 17.86%, the total number of 10kg products is 29, accounting for 23.81%, the total number of 12.5kg products is 7, accounting for 16.07%, and the total of 50 products is afraid of extrusion, accounting for 29.76%. Although different distribution vehicles have different packing modes and different loading rates, the optimized distribution vehicles have increased the loading

rate as much as possible, and the average loading rate has been greatly improved.

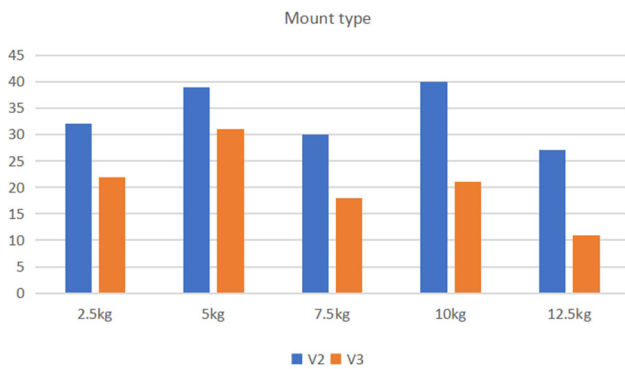


Figure 6. Comparison of loading types of vehicle 2 and vehicle 3

In addition, the three-dimensional packing diagram of vehicle 2 was drawn using Python, as shown in Figure 7.

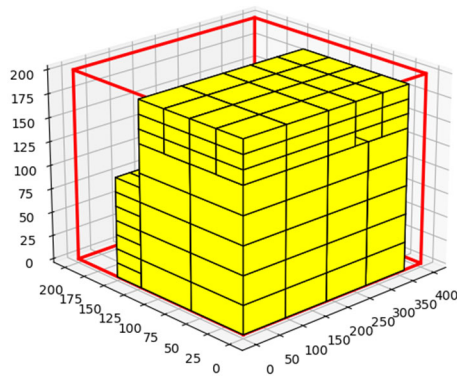


Figure 7. Vehicle 2 loading diagram

## 6. Conclusion

In this work, The route problem of loading homogeneous fleet vehicles in 3D (3L-CVRP) was reconsidered, and it is applied to the transportation of fresh agricultural products. This problem combines two complex combinatorial optimization problems, namely the Center Vehicle Routing

Problem (CVRP) and the Three-dimensional loading problem. Although the transportation problem of using a single-center vehicle seems to be a common problem.

Since 3L-CVRP is a challenging NP-Hard problem of high complexity; it is solved using meta-heuristics. Our proposed approach integrates a GA-TS algorithm that was originally developed for the 3L-CVRP problem.

This paper considers the joint optimization of distribution and loading of multi-category fresh agricultural products, and considers the characteristics of fragile, afraid of extrusion and poor load-bearing capacity of some fresh products in the process of joint optimization. Firstly, a joint optimization model is constructed, which converts the multi-objective problem with the largest average loading rate, that is, the smallest number of vehicles used and the smallest mileage, into a single-objective function with the lowest cost. Secondly, an improved genetic algorithm model is proposed for joint optimization problems, and multiple sets of parameter values are set, each set of parameter values is operated independently 20 times, and finally the number of parameter better values is

set as: initial population size = 200, number of iterations = 1000, mutation probability = 0.02, cross probability = 0.8 is better.

This chapter uses the random selection of demand points in a certain area of Shanghai as an example of the joint optimization problem of 3D packing and distribution routes for multi-product orders, and verifies the effectiveness of the model and algorithm. Comparing the distribution schemes before and after optimization, it can be found that different distribution schemes and loading schemes affect the average loading rate (i.e. the number of vehicles used) and the reduction of delivery mileage, which directly affects the total transportation cost. Distribution centers have found that proper stacking can effectively ensure increased vehicle load rate levels and reduced total transportation distances, thereby reducing the operating costs of the enterprise.

The future works could further assess:

- The proposed approach to solve different of the routing aspect (CVRP) features such as time window constraints(3L-CVRPTW).
- The loading sub-approach to consider other practical constraints such as load balance constraints.
- The improvement of the computation time by improving the association of the routing problem with the loading sub problem.

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