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# Research on consumable distribution mode of shipbuilder's shop based on vehicle routing problem

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ABSTRACT: A distribution vehicle optimization is established with considerations for the problem of long period of requisition and high shop costs due to the existing consumable requisition mode in shipbuilder's shops for the requirements of shops for consumables. The shortest traveling distance of distribution vehicles are calculated with the genetic algorithm (GA). Explorations are made into a shop consumable distribution mode for shipbuilders to help them to effectively save their production logistics costs, enhance their internal material management level and provide reference for shipbuilder's change in traditional ways and realization of just-in-time (JIT) production.

*Keywords*: shipbuilder; consumable distribution; vehicle routing problem (VRP)

## 1 INTRODUCTION

According to the Economic Performance of Shipbuilding Industry in 2015[1], the shipbuilding industry in China is confronted with many challenges leading to ongoing difficulties to make profits. Segmentation of shipbuilder's management objectives has turned to be a must. Shipbuilders fall into the scope of the traditional processing and manufacturing enterprises. Consumables (fasteners, welding consumables, tools) for shops are required in large quantities and consumed very quickly. Existing shops generally assign personnel to the warehouse for requisition of consumable insufficiency. However, shops are far away from the warehouse. This mode does not only consume large quantities of labor resources but also leads to disorderly traffic in the factory. For this reason, the delivery of consumables to each shop simultaneously turns to be effective. So, how consumables can be distributed and the minimum delivery fee can be achieved remains a problem to be solved. Domestic and foreign scholars have conducted several studies on this issue. A vehicle routing problem (VRP) model is established. A series of algorithms are proposed to solve the model: Tu Yilin [2] studied the distribution problem in the catering industry. She proposed that the distribution mode should be determined by the categories of goods. The study was conducted in terms of selection of distribution points and the routing change plan. GAO Guibing [3] set up a distribution vehicle routing optimization model aiming to achieve the shortest vehicle traveling distance, maximum vehicle utilization and fewest times of distribution in term of optimal distribution routing of materials in flow manufacturing system. Solutions are obtained with the double-layer progressive multi-objective optimization algorithm and demonstrated by examples for validity. Du Jiwang and Wang Jinjian [4] optimized the layout of ship building block assembly area with improved GA. They developed a material layout plan and planned transportation routing of materials, solving the problem of obstacle-avoiding path in transportation. Wang Xiao [5] obtained an optimal vehicle routing with GA and demonstrated its validity for the problem that tobacco distribution in small-and- medium-sized cities can only route distributors once. Zhang Caifang [6] analyzed key processes of production logistics of discrete manufacturers and designed a functional model for logistics distribution optimization, which effectively solves the problem of selecting a material distribution vehicle routing within shops.

In conclusion, scholars at home and abroad have made achievements on VRP studies. However, there is a lack of study on consumable distribution of ship-

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builders. Production tasks and technologies differ in each shop of shipbuilders. Whether consumables can be delivered to the shop quickly relates to timely completion of production tasks on time and affects delivery time. For this reason, we make studies on the establishment of a shop consumable distribution model for shipbuilders; Use GA to obtain solutions according to the actual conditions of shipbuilders; make measurements with actual data to optimize the distribution vehicle routing so that the total mileage is the shortest and traveling time is reduced. This is of great significance for shipbuilder's improving consumable management level, strengthening business management and sharpening core competitiveness of enterprises.

## 2 CONSUMABLE DISTRIBUTION MODE OF SHIPBUILDER'S SHOP

### 2.1 *Process*

The traditional way of consumable requisition can no longer adapt to the requirements of heavy production tasks and this turns to be a major factor which hinders improvement of shop production efficiency. To completely solve the problem of consumable supply mode, a shop production-oriented consumable distribution mode should be established according to the shop consumable requirements and the process of material distribution. The routing is as follows:

(1) Summarize the requirement information in advance. The shipbuilder's ERP system set up an information sharing platform. The Material Department issues a consumable application notice to job shops. The shops submit the requirement information including type, specification, quantity and time of consumables to the Material Department within a given period.

(2) Have a quick check on the inventory information. The Material Department looks up the inventory information of requisition application made by the shops. If exiting consumables in the warehouse can meet the requirements, an immediate approval will be given to the consumable warehouse. If existing inventory is insufficient, a procurement plan is needed to top up the inventory as early as possible.

(3) Develop scientific distribution plans. The consumable warehouse finishes material sorting and packaging according to the requirements, and then develops a distribution plan, including preparing the distribution vehicles and setting the distribution routing based on the position of production shops. The distribution warehouse arranged centralized distribution to the shops at fixed time, and external logistics should be managed simultaneously in the shipbuilder's factory. In addition, transport within the factory should be properly arranged, and road control is needed when necessary.

(4) Improve the return of excess material to the warehouse. During actual production and manufacturing, a change of production technology may lead to the occurrence of excess consumables in shops. These shops may load excess materials into the vehicle after unloading by virtue of the distribution mode. These materials are brought back to the consumable warehouse by distribution vehicles. This not only increases utilization of materials but also creates benefits for shipbuilders.

### 2.2 *Characteristics*

Compared to the traditional consumable requisition mode, the consumable distribution mode is characterized with the following factors:

(1) Temporary booking is reduced for improved management quality. The consumable warehouse has a function of changing from approval in the past to initiative distribution. Consumables within the defined area are sorted and packaged by the consumable warehouse to provide the consumable material packages required by each shop. Distribution vehicles are assigned for real-time distribution to the designated shops.

(2) Handover procedures are simplified; material management is strengthened. Goods handover procedures under the traditional requisition mode are complicated and subject to errors. Upon release of the distribution mode, shipbuilders can connect material software with distribution and unloading. Receivers in each shop scan the QR code of consumables for reception with an electronic device. The relevant data and information is sent to the shop and the Material Department on a real-time basis. This saves the time spent on card punching and completion of a form. It also provides real-time and effective records for the material management department to facilitate material management.

(3) Turnover is reduced to save capacity costs. With the distribution mode, production shops no longer assign workers to the warehouse to pick up consumables, greatly reducing disorderly turnover in the factory. Instead, fast and efficient transportation is achieved by distribution vehicles. It does not increase the workload of production workers or interfere with normal production and manufacturing order. It also will not lead to additional costs of the shop and saves costs for production shops.

## 3 VEHICLE ROUTING MODEL FOR CONSUMABLE DISTRIBUTION OF SHIPBUILDER'S SHOP

### 3.1 *Description of the problem*

For consumable distribution from the consumable warehouse to n shop(s), assuming that the requirement of shop $i$ is $g_i$ ($i$ = 1, 2…$n$); the carrying capacity of each distribution flat car is $G$ and $g_i \le G$; m denotes the number of vehicles for distribution. Consumables are distributed from the consumable warehouse in the factory with the consumption of consumables required by job shops and the duration in a rationally optimized sequence. The coordinates of positions where the distribution center and customers are located are known. It is known that goods requirements of customers are less than the carrying capacity of the distribution vehicle. Each vehicle starts from and returns to the distribution center after finishing the delivery to several customers. It is defined that the goods requirements of a customer should be delivered with one distribution vehicle. Distribution to customers is required to be completed with fewest vehicles and minimum total vehicle mileage. The objective of this problem study is to find an optimal distribution routing (the shortest time, or lowest transportation cost or the shortest distribution routing) under given conditions (required duration, place and number of requirements).

## 3.2 *Modeling*

In order to complete the distribution task with fewer vehicles, the number of vehicles provided should not be greater than the quotient of the sum of requirements of all shops and the maximum load per vehicle considering the actual conditions. It is known that an integer maxima that is not greater than the one in the bracket can be obtained with Gauss integer function. For this reason, Gauss integer function is used here to determine the number of vehicles used, that is:

$$m = \left\lfloor \sum_{i=1}^{n} \frac{g_i}{G} \right\rfloor + 1 \tag{1}$$

Assuming that the consumable warehouse is numbered 0, the number of production shops should be i ($i$=1, 2… m); and the number of vehicles for distribution should be $k$ ($k$=1, 2…m). The variable is defined as follows: $x_{ijk}$ =1 means k drives from $i$ to $j$, others; $x_{ijk}$ =0; $y_{ik}$ = 1 means the requirement of $i$ is met by $k$, others $y_{ik}$ = 0.

All $c_{ij}$ denotes the length of haul from shops from $i$ to $j$. For simplified operation, total mileage $Z$ of the vehicle used is to study the transportation cost of the model. So, the mathematical model of VRP is as follows:

$$\min Z = \sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{k=1}^{m} c_{ij} x_{ijk} \tag{2}$$

$$\sum_{i=1}^{n} g_i y_{ik} \le G, k = 1, 2...m \tag{3}$$

$$\sum_{k=1}^{m} y_{ik} = 1, i = 1, 2...n \tag{4}$$

$$\sum_{i=0}^{n} x_{ijk} = y_{jk}, j = 1, 2...n \tag{5}$$

$$\sum_{j=0}^{n} x_{ijk} = y_{ik}, i = 1, 2...n \tag{6}$$

$$y_{ik} = 0 or 1, i = 1, 2...n \tag{7}$$

In the above models, equation (2) is the objective function under which the minimum total mileage of the vehicle is achieved while meeting the requirements of all shops for consumables; equation (3) is the vehicle capacity constraint that ensures that the traffic volume of consumables delivered to each shop per distribution is not more than the maximum capacity of a vehicle; equation (4) denotes that the transportation to each shop is completed with only one vehicle and all transportation tasks are completed with $m$ vehicles; equations (5) and (6) restrict that there should be only one vehicle arriving at or leaving a shop; equation (7) is the range of the value of a parameter.

## 3.3 *Genetic algorithm solution*

Genetic algorithm (GA) is an intelligent algorithm that has high robustness and the global optimization capability and is for solving complex multi-extreme optimization and combinatorial problems. It is also one of the important ways solving VRP problems. [7]The category of consumables is not allowed in modeling in this paper to keep things simple.

### 3.3.1 *Chromosome coding* [8]

The natural number coding approach is used in this paper to facilitate computer processing. The natural number 0 is denoted the consumable warehouse, $i$ ($i$=1, 2…n) denoted the shops, using m vehicles to deliver consumables to the shop numbered $i$. Each and every vehicle departs from the warehouse and finally returns to the warehouse throughout the process of distribution. The number of code 0 in chromosome coding should be "$m+1$" which means that the warehouse splits the code into segment(s) so that sub-route(s) is provided and represents that all distribution tasks are completed with m vehicles(s). For example, chromosome "0125043098670" actually denotes the routing arrangement that three vehicles complete the transportation tasks of 9 distribution points; the first vehicle transports consumables from the warehouse to shops 1, 2 and 5 and returns to the warehouse at the sub-route "0→1→2→5→0". Similarly, the second vehicle follows the sub-route "0→4→3→0", and the third vehicle follows the sub-route "0→9→8→6→7→0".

### 3.3.2 *Population initiation*

The initialized population may generate numbers from 1 to $n$ to ensure that the initial production is of superiority and provides the algorithm with faster rate of convergence. $n$ randomly arranged number(s) represents that the sequence of distribution for $n$ customer(s) is randomly arranged so that a chromosome is formed up to meet the requirements of the problem till a number of chromosomes are generated to form the initial population.

### 3.3.3 *Fitness function*

It is assumed that the fitness of each chromosome is: *F*=2000/*L* (the value may be either 2,000 or any integer, whichever is simpler). *L* is the total length of the routes within each chromosome. The penalty function is obtained:

$$p=\begin{cases}(v-v_a)v_a, v_a>v\\0, v_a>v\\1, F>1\end{cases}$$

$v_a$ is the maximum carrying capacity of a vehicle. $v$ is the sum of required traffic volume of a possible route within each chromosome. The final fitness function of each chromosome is: *Fitness* = (1 – *p*)* *F* [9].

### 3.3.4 *Selection operator*

The selection function used is generally the proportional selection operator. A selection factor is randomly generated by the roulette wheel approach in this paper. The factor is bonded with the relevant fitness to select the target chromosome. The chromosome with the maximum fitness among these of each population is directly replicated and goes to the next generation. Other chromosomes in the population are distributed by the probability of their fitness and generate filial generations with the roulette wheel approach. It ensures that the best one survives the next generation and the rest ones generate filial generations with the struggle for existence approach, which achieves globally optimal convergence of the algorithm.

### 3.3.5 *Crossover operator*

The recombination crossover approach is used in this paper to improve the diversity and rate of evolution of chromosomes.

### 3.3.6 *Mutation operator*

Chromosomal variation increases to an extent the diversity of population. The approach that the positions of 2 genes in chromosomes of an individual are randomly interchanged is used in this paper.

## 4 DEMONSTRATION BY EXAMPLES

CX Shipyard is a large and medium-sized shipbuilder in China. It is understood that this company follows the mode that “application is made on a provisional basis; self-pickup is seen in shops” in terms of consumable management. Nearly one thousand requisitions occur in a day in the factory. High costs and expenses are incurred against the shop due the consumables requisition of single item. In addition, when there are arduous production tasks, a sudden increase of requisition by shops may occur, resulting in long time in sorting and packaging by the warehouse and disorderly traffic in the factory, and thus affecting continuous and efficient operation of the production workshop and even the building of a ship as a whole. For this reason, the mentioned model is applied in the consumable distribution problem of the company to demonstrate its effectiveness.

This shipyard has 1 consumable warehouse and 7 job shops (hull, mechanical, processing, cold work, marine engine, docking and fitting-out). With an advanced production management system, the company provides the quantity of work and consumption of required consumables during shipbuilding. The requirements of each shop for consumables are shown in Table 1. The warehouse has sufficient vehicles for goods distribution, each with a carrying capacity of 8t. The known distance between the warehouse and shops is shown in Table 2 (0 denotes the warehouse). It is required that the connection between vehicles and shops should be properly determined. Vehicle routing should be provided to minimize the aggregate operating cost, which is to minimize the total transport mileage provided that the constraints including carrying capacity of vehicles and requirements of shops are in full consideration.

A distribution model should meet: (1) The sum of requirements for painting at demand points along each distribution route is no greater than the carrying capacity of each vehicle for distribution; (2) The length of each distribution route is no greater than the maximum traveling distance of a vehicle per distribution; and (3) The requirements for painting at demand points must be met and can only be delivered by a vehicle for distribution.

Table 1. Requirement of job shops for consumable warehouses (t)

| Shop | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Requirements | 1.5 | 1 | 1 | 2 | 1 | 3.5 | 2 | 2 |
| Vehicle capacity | | | | 8 | | | | |

Table 2. Distance between consumable warehouse and shops with requirements (m)

| | Ware house | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Ware house | 0 | 400 | 360 | 320 | 560 | 480 | 440 | 800 |
| 1 | | 0 | 160 | 200 | 240 | 120 | 480 | 560 |
| 2 | | | 0 | 240 | 400 | 320 | 480 | 240 |
| 3 | | | | 0 | 320 | 640 | 320 | 160 |
| 4 | | | | | 0 | 400 | 480 | 560 |
| 5 | | | | | | 0 | 240 | 320 |
| 6 | | | | | | | 0 | 560 |
| 7 | | | | | | | | 0 |

According to equation (1), the total requirements for consumables of each shop are 15t. It is calculated that 2 vehicles are needed for the distribution. VB.NET procedure is prepared according to the above GA. An experimental computation is employed to solve the route optimization problem that 1 consumable warehouse is provided with 1 vehicle that undertakes distribution to 7 shops included in this example. GA parameters are: the population size is 20; the crossover and mutation probabilities are 0.95 and 0.05, respectively; the iteration is 50. The number of gene exchange upon variation is randomly selected. An optimal distribution route is obtained by genetic evolution: shop 5 → shop 6 → shop 7 → the warehouse → shop 1 → shop 2 → shop 3 → shop 4. The minimum distribution distance is 3,760m, which is far shorter than the vehicle traveling distance due to the self-requisition by shops shown in Table 3. The results show that this model generates a distribution route with the minimum distribution distance quickly, providing great support for shipbuilders in terms of consumable distribution management, achieving real-time distribution and ensuring smooth shop production.

Table 3. Comparison between consumable distribution and requisition effects

| | Distribution mode | Requisition mode |
|---|---|---|
| Vehicle traveling distance (m) | 3,760 | 6,480 |

## 5 CONCLUSION

This paper discusses the establishment of distribution mode of consumables for shipbuilders. With modern logistics technology, GA approach is used to solve VPR of consumable distribution, addressing the distribution problem of consumables required by shipbuilder's shops with minimum distance. Compared to the traditional mode, this approach is remarkably effective. This program put forward effective solutions of the waiting problem arising from untimely distribution of consumables during shipbuilding. It is of high value of application in practices, both reducing the consumable distribution costs and serving as a reference for the distribution of other materials other than consumables. It is an effective management tool that enables just-in-time production of the shipbuilders and helps the enhancement of their core competitiveness.

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