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# Routing of Small Party Cargo Flows in Cars

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**ABSTRACT:** To date, universal routing methods for the transportation of small-lot cargoes have not been developed. In cases where the number of loading points is small, the problem can be solved by comparing all the options. But due to the large number of points, this problem cannot be solved. But there are several methods for finding the optimal route system in shorter ways without checking the parameters, and these methods allow you to find solutions that are close to the optimal option.

This article discusses the issue of determining the rational sequence for the delivery of small-lot cargo to consumer points and the inclusion of consumer points in routes, taking into account the carrying capacity of the vehicle. The possibilities of practical application of the Clark-Wright method in solving problems are shown and a specific problem is solved.

**KEYWORDS:** small-batch cargo, routing, rational, consumer, transportation costs, method, initial plan, algorithm, radial, combining routes, carrying capacity.

## I. INTRODUCTION

The need to take into account the small batch of cargo transported in the assessment of the efficiency of truck transport was proposed by L.V. Kantorovich [1].

Small-batch transportation routing means the creation of a series of rational distribution or collection routes of cargo and passengers from one point to several addresses. Mathematically, the problem is to define a scheme that connects several addresses, with the starting and ending points being the same and passing through the remaining addresses only once. In its simplest form, this problem is reduced to the classic "commuter problem" of mathematics.

The process of transportation includes loading and unloading of goods on the vehicle, movement of the loaded vehicle from the place of departure to the destination, unloading and receiving cargo, as well as the movement of vehicles for the next flight to the destination.

The urgency of the research is to increase the scientific level of economic solutions and reduce transportation costs based on the improvement of small-volume cargo transportation.

Hence, the purpose of the study was to: use the Clark-Wright method in solving the routing problem; make recommendations for practical application.

The issue of road routing was proposed in 1959 by George Dantsig and John Ramser [2] and is an important issue in the field of transport, distribution and logistics.

In recent years, the development of trade, population growth in large cities, positive changes in demand for urban ecology, as well as the implementation of transport infrastructure and digital economy in the country require the development of new effective information computing technologies to optimize transport infrastructure in the region.

## II. MATERIALS AND METHODS

It is known that when routes are created on the basis of the shortest connecting network, two interrelated issues are solved in series:

1) determination of the rational sequence of cargo transportation to the addresses;

2) inclusion of points on the routes, taking into account the car load capacity.

The Clark-Wright method allows to solve these two problems at once, that is, to create rational routes for rolling stock with different payloads.

The essence of the method is as follows.

First of all, an initial plan of transportation is made. In this case, each recipient is allocated a separate pendulum (radial) route, and a car with a lift corresponding to the amount of cargo transported (Figure 1). In subsequent

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iterations, the two pendulum routes are paired with each other, resulting in a distribution route (Figure 2). The remaining pendulum routes and the distribution route are combined, and the option is chosen so that the pairing results in a maximum reduction in transportation costs. If it is not possible to reduce costs as a result of any subsequent pairing, or if the volume of traffic on the combined route exceeds the load capacity of the rolling stock, then the unpacking process is stopped and the plan found is considered optimal.

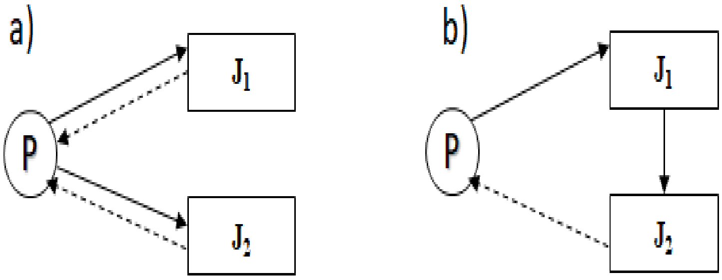


**Figure 1. a) Radial route; b) ring route.**

In the first case, the total travel time is as follows

$$t_1 = 2t_{j_1} + 2t_{j2} \quad (1)$$

In the second case, the total travel time is as follows:

$$t_2 = t_{pj_1} + t_{j_1 j_2} + t_{j_2 p} \quad (2)$$

The value of the time gain when the two radial routes are combined is as follows:

$$\Delta t_j = (t_{pj_1} + t_{j_2 p}) - t_{j_1 j_2} \quad (3)$$

The Clark-Wright method is the most optimal for solving such problems.

[3] Based on the Clark-Wright algorithm, opportunities to reduce transportation costs of product delivery in populated areas have been demonstrated. This method allows you to get a plan close to the optimal and use a computer to solve the problem of distribution of cargo to the points. The advantages of the method are its simplicity, reliability and flexibility, which allows to take into account additional factors influencing the final solution of the problem.

Improvements to the Clark-Wright method using the Floyd-Warsella and Dextry algorithms have been proposed [4].

| Cars | Number of cars | | |
|---|---|---|---|
| | 4 т | 5 т | 6 т |
| Used<br>Empty space | 8<br>2 | -<br>3 | -<br>4 |

***Table 1***
**Initial plan for the use of vehicles**

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We will look at specific examples of how the Clark-Wright method can be applied [5]. We were given 8 consignees and the amount of cargo to be delivered to them is shown in the first column of Table 1. 10 units with a capacity of 4 tons, 3 units with a capacity of 5 tons and 4 units with a capacity of 6 tons were allocated for transportation. Let's say in the initial plan we separate one car from a car with a carrying capacity of 4 tons for each recipient (Table 1.

Now let's look at the procedure for calculating the values in Table 2. The first column shows $P_0$ the time of delivery to all receiving addresses $P_j$ ( $j$=1,2,…..,B)from the point of departure. This time ( $t_j$ ) onsists of the times of loading ( $t_j^0$ ) walking ( $t_j^{ю} = l_j / V_T^j$ ) and unloading ( $t_j^T$ ).The columns are then divided into two $P_1$, $P_2$, ……. , $P_j$ with the walking times on the left and the decrease (gain) values of the load carrying time when the two pendulum routes are combined on the right

**Table 2**

**The value of achievements when combining inter-point travel times and routes**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_0$ | | | | | | | | | | | | | | | |
| 0.8 | 11 | $P_1$ | | | | | | | | | | | | | | |
| 0.9 | 16 | 4 | 23 | $P_2$ | | | | | | | | | | | | |
| 1.2 | 20 | 6 | 25 | 14 | 22 | $P_3$ | | | | | | | | | | |
| 1.6 | 26 | 7 | 30 | 18 | 24 | 26 | 20 | $P_4$ | | | | | | | | |
| 1.4 | 32 | 9 | 34 | 16 | 32 | 28 | 24 | 22 | 36 | $P_5$ | | | | | | |
| 1.5 | 36 | 6 | 41 | 20 | 32 | 20 | 36 | 26 | 36 | 32 | 36 | $P_6$ | | | | |
| 1.1 | 39 | 5 | 45 | 17 | 38 | 16 | 43 | 34 | 31 | 42 | 29 | 51 | 24 | $P_7$ | | |
| 1.3 | 44 | 10 | 45 | 16 | 44 | 22 | 42 | 36 | 34 | 46 | 30 | 55 | 25 | 58 | 25 | $P_8$ |

For example let's calculate $P_1$ and $P_2$ the win value when and the pendulum routes are interconnected. the time to transport cargo from point $P_0$ to point $P_1$ is $t_{01} = 11$ minutes, to $P_2$ is $t_{02} = 16$ minutes. If these two routes are combined, then the load is carried from point to point $P_2$ without returning. In such cases, the shipping time will be from $t_{01} + t_{11}$. point to point without returning. In such cases, the shipping time will be from. Since the distance matrix is symmetric, the gain value can be calculated from the above times:

In option 1 $P_1$ ter the load is delivered to the point, it is said again $P_0$ (the value of this time is in $t_{10} = t_{01} = 11$ minutes), and then the load is brought from $P_0$ to $P_2$ ( $t_{02} = 16$ minutes).

In option 2 the load is transported to the point $P_1$ to $P_0$ without returning to $P_2$ ( $t_{12} = 4$ minutes). Thus, in this option, i.e., the value of the time gain when the routes are combined is in $(t_{10} + t_{02}) - t_{12} = 11 + 16 - 4 = 23$ minutes.

Let's say routes 2 and 3 are combined, then the winning value is

$$t_{20} + t_{03} - t_{23} = 16 + 20 - 14 = 22 \text{ minutes.}$$

Since our next calculations only need the value of achievements, we include them in a separate table (Table 3). The total delivery time when the carriage is performed on pendulum routes is found as follows.

$$T_{emm} = 2 \sum_{j \in (1-8)} t_{oj} = 2(11+16+20+26+32+36+39+44) = 448 \text{ мин.}$$

Now let's look at a way to combine routes, taking into account the value of achievements. To do this, we add a separate column of indicators $J$ to the achievement matrix. Assume that if the $P_j$ point to be included in the route is

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the start or end address, the value $J$ in the column $I$ of this row will be 0 if it is an internal point, and 2 if the pendulum is to be included in the route. For the initial plan, all values $J$ in the column will be 2.

**Table 3**
**Initial achievement table**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $P_8$ | 25 | 25 | 30 | 34 | 42 | 44 | 45 | 2 | 1.3 |
| | $P_7$ | 24 | 29 | 31 | 43 | 38 | 45 | 2 | 1.1 |
| | | $P_6$ | 36 | 36 | 36 | 32 | 41 | 2 | 1.5 |
| | | | $P_5$ | 36 | 24 | 32 | 34 | 2 | 1.4 |
| | | | | $P_4$ | 20 | 24 | 29 | 2 | 1.6 |
| | | | | | $P_3$ | 22 | 25 | 2 | 1.2 |
| | | | | | | $P_2$ | 23 | 2 | 0.9 |
| | | | | | | | $P_1$ | 2 | 0.8 |
| | | | | | | | | У | Carrying capacity |

The largest (45) of the elements of the achievement matrix is ($P_1$, $P_7$ ) selected. This shows the routes( $P_1$ , $P_7$ ).that give the greatest success when combined. $P_0 - P_1 - P_0$ and $P_0 - P_7 - P_0 = P_0 - P_1 - P_7 - P_0$ . In the column of the achievement $J$ matrix and the values $P_1$ $P_7$ of the rows are changed from 2 to 1. The carrying capacity on the distribution route will be $Q_1 + Q_7$ =1+1.1=2.1 tones. In the initial plan for the use of cars, one car was allocated for each pendulum route. Since a car is needed for the distribution route $I$ found, the number of cars used in the plan (Table 1) is reduced to one.

Let's see if you can add more addresses to the route found $P_0 - P_1 - P_7 - P_0$ . $P_1$

To do this, we determine the maximum win value in the column ( $P_7$ excluding). the gain in the column of the row is 45, which is the largest. Hence, the address must be entered into the formed distribution route. Here we create the following route:

$$P_0 - P_8 - P_1 - P_7 - P_0$$

The volume of cargo transported on this route will be $Q_8 + Q_1 + Q_7$ =1+1.1+1.3=3.4 t. $P_1$ we change the value in the column $J$ from $I$ to 0 because this point has become an internal point in the route, and we change the value of from 2 to 1.

$J$ since the column has two rows ( $P_7$ , $P_8$ ) values, it is necessary to find the largest win value in these rows. Since this value is 43 and is in the cell where the column and row intersect, it is advisable to enter the address in the above route. So we create a new route:

$$P_0 - P_8 - P_1 - P_7 - P_3 - P_0$$

The volume of traffic on this route:

$$Q_3 + Q_8 + Q_1 + Q_7 \text{=1.2+1.3+0.8+1.1=4.4 t.}$$

Since the constructed route becomes an internal point, we convert its value in the column from to 0. On this route we will allocate a vehicle with a load capacity of 5 t for transportation. We will also make appropriate changes to the plan for the use of cars, ie the number of used cars with 4 tons will change from 8 to 4, instead of one car with 5 tons will be used.

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The achievement matrix and the vehicle utilization plan generated by the constructed route are presented in Tables 3-4. By following the steps outlined above, we determine the following distribution route:

$$P_0 - P_6 - P_5 - P_4 - P_2 - P_0$$

Traffic volume on the specified route will be

$Q_6 + Q_5 + Q_4 + Q_2$ =1.5+1.4+1.6+0.9=5.4 t. This means that one truck of 6 tons should be allocated for transportation.

**Table 4**
**The plan of using cars**

| Carrying capacity | *J* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.8 | 0 | $P_1$ | | | | | | | |
| 0.9 | 2 | 23 | $P_2$ | | | | | | |
| 1.2 | 1 | 25 | 22 | $P_3$ | | | | | |
| 1.6 | 2 | 30 | 24 | 20 | $P_4$ | | | | |
| 1.4 | 2 | 34 | 34 | 24 | 36 | $P_5$ | | | |
| 1.5 | 2 | 41 | 34 | 36 | 36 | 36 | $P_6$ | | |
| 1.1 | 0 | 45 | 38 | 43 | 31 | 29 | 24 | $P_7$ | |
| 1.3 | 1 | 45 | 44 | 42 | 34 | 30 | 25 | 25 | $P_8$ |

| Cars | Quantity of cars | | |
|---|---|---|---|
| | 4 т | 5 т | 6 т |
| Using | - | 1 | 1 |
| Empty | 10 | 2 | 3 |

Thus, it is advisable to carry out the freight plan on distribution routes 2 with 6-ton trucks (the initial plan for the use of cars is to allocate 8 4-ton trucks for service on these routes according to Table 1).

Let's calculate the time of cargo distribution on the constructed routes:

For route I:

$$T^1_{емк} = t_{08} + t_{81} + t_{17} + t_{73} + t_{30} = 44 + 10 + 5 + 16 + 20 = 95 \text{ minutes}$$

For route II:

$$T^2_{емк} = t_{06} + t_{65} + t_{54} + t_{42} + t_{20} = 36 + 32 + 22 + 18 + 16 = 124 \text{ minutes.}$$

Total shipping time

$$T^{ум}_{емк} = T^1_{емк} + T^2_{емк} = 95 + 124 = 219 \text{ minutes}$$

## III. CONCLUSION

Reduction of load delivery time compared to the first option on the constructed rational routes

$$\Delta T_{емк} = T_{емк} + T^{ум}_{емк} = 448 - 219 = 229 \text{ minutes}$$

Computer programs can be used to find the optimal route options based on the Clark Wright method. will be published in future editions.

This article describes the results of research work in the framework of the practical project №OT-Atex-2018-352 "Wide application of logistics principles in the optimal development of the regional transport network and the effective use of future freight flows."

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