DELIVERY PROBLEM SOLUTION FOR SMALL-CARGO PHYSICAL DISTRIBUTION CONTROL

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Abstract. The paper deals with the main small-cargo physical distribution control problems and their solutions. Traffic congestions in cities are not constant; so it is impossible to use only standard route planning methods for efficient physical distribution control. It is significant to use vehicles optimally; to find the optimal number of vehicles. Company should find also the best objects' serving radius to achieve the best profit. It is necessary to compare the costs and revenue for different opportunities.

Keywords: accuracy, delivery, optimization, vehicle.

Introduction

Either the manufacturer or the trading enterprise should solve the physical distribution control problem nowadays. The accuracy factor is very significant for small-cargo physical distribution control, especially for cities and other built-up areas, when it is necessary to serve many customers. It is important to optimize the delivery process to achieve accurate results.

There are different ways to reduce logistic costs within physical distribution control. It is possible to use one's own transport or buy transport companies services to accomplish the delivery process. It is very important to create routes optimally to satisfy the customers' demands and reduce the costs for companies as well.

Own transport or commercial transport (forwarder) service

On the one hand, a manufacturer or trading company has many different advantages if it has its own transport. On the other hand, using of one's own transport is connected with the following disadvantages:

- variable costs are going up due to idle running back and vehicle idle time;
- company needs additional investments for vehicles, garage and special inventory acquisition;
- overhead expenses are going up;
- company is responsible for cargo safety within the delivery process.

Usage of commercial transport services also has both - advantages and disadvantages. So, it is a very significant problem – to solve, what is the best way to manage the physical distribution process optimally – using one's own transport or buying transport services from another company. It is possible also to use the own transport and commercial transport service combination.

Logistic managers have to plan all logistic costs groups, connected with own transport operation. The main groups of costs are the following:

- drivers' salary costs C_s;
- fuel costs C_f;
- lubricant costs C_l;
- repair costs C_r;
- vehicle depreciation costs C_d;
- overhead expenses C_o.

Transportation costs for the particular route may be calculated using the Formula 1:

$$C_{\mathrm{tr}} = C_f+C_s+C_l+C_r+C_d+C_o. \quad (1)$$

If a firm buys transport services from the forwarder, it should remember, that service prices on the one hand, cover the transportation costs for the forwarder; on the other hand it also provides a profit.

For example, we may investigate a situation, when a particular company plans to send 4 m^3 from the capital of Latvia (Riga) to another city of Latvia (Liepaja). The total distance is 260 km. If the company realizes this process by its own transport, it has the following structure of costs (Table 1):

Table 1

Company transportation costs to serve Riga-Liepaja route

Costs positions	Value, LVL
Drivers' salary	27.35
Fuel costs	27.59
Lubricant and other materials	0.70
Vehicle repair costs	17.27
Tire renovation and repair	4.10
Vehicle depreciation costs	9.60
Overhead costs	5.20
Total	**91.81**

But, if the firm uses a forwarder service, it pays more. In this case the firm should pay for the service 155 LVL (appr. 69 % more, than using own transport).

It is not easy to measure the delivery quality factor. This factor is too subjective, because good quality delivery is when the customers are satisfied. It is easier to achieve it using own transport, not the forwarder service. The main elements to measure the quality of delivery are:

- total time of delivery;
- accuracy factor of delivery.

On the one hand, it is simpler to control physical distribution, using one's own transport. Firstly, it is possible to plan routes optimally, considering cost minimization and specification of customers' needs. Secondly, it is easy to instruct drivers to serve customers in the best way. Thirdly, if company has its own transport, it is possible to tool it up by special equipment to make the delivery process easy.

On the other hand, there is also another point of view. Some specialists think that forwarder companies provide better delivery due to their professionalism and qualification. It is possible to choose the best forwarder using the following evaluation criteria:

- total transportation time for a particular route;
- regularity of transportation process for this direction;
- forwarder's additional service without transportation;
- quality of forwarder's staff;
- forwarder is ready to start a dialog about how to increase the level of quality or decrease the price of the delivery.

Routing problem into physical distribution control

There are many special methods and also computer programs that may be used to solve particular time-planning problems, connected with routing. But every method or program has different disadvantages, talking about route planning within cities, towns and other built-up areas. For instance, mathematical methods need fixed information about time, speed and other factors, but in our case these factors change; so it is impossible to achieve the optimal result using only mathematical methods. In this case it is possible to achieve the optimal result, using only specialized methods, programs and the experience of specialists combined.

It is possible to use only the micro-elements method to improve route planning in cities with intensive and unstable traffic. To explain it we may investigate the following example.

The micro-elements method is very useful to solve logistic problems for small-cargo physical distribution control. The time of delivery consists of two basic positions: time of driving and time of loading/unloading. The task of the specialist is to consider these elements for the particular route. It is possible to plan driving time precisely, if we use the following approach for solving the routing problem.

1. To create the road data base. It is necessary to divide the roads of a particular into different elements.
2. Notice, what is the average speed of driving at particular hours for each element.
3. To create a data base of the average speed for each element into particular hours of the day.

If the specialist creates this data base, he will avoid different problems connected with circular routes planning for cities with intensive traffic [3]. Actually, if the distance of the particular road element is known as well as if we know the vehicle speed in this at the particular hour, we may plan the time we spend to drive through this element. Of course, it makes the route planning process easier. It is possible to improve the customer service level of delivery.

Delivery process organization in practical conditions

There is not one universal recommendation, whether it is more expedient to use own transport or forwarder transport services in real conditions. Many specialists consider that the best variant is to use one's own transport combined with forwarder commercial transportation services (Figure 1).

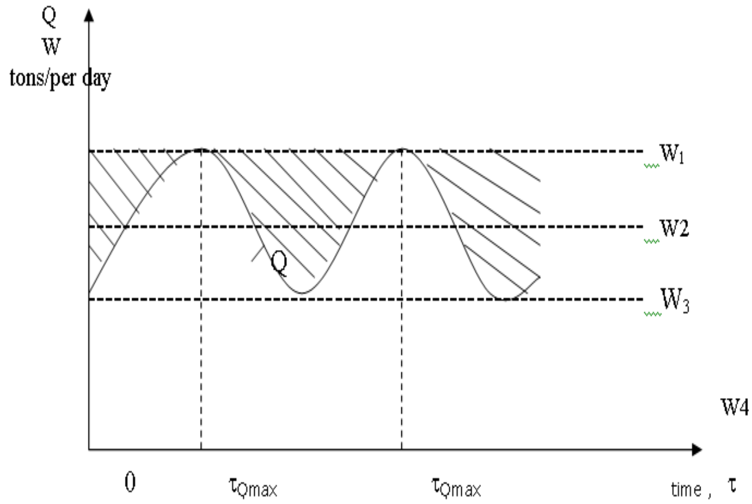

Fig. 1. **Own transport and commercial service combination:** Q – delivery volume fluctuations for period; W_1 – own transport capacity is in line with maximal volume of delivery; W_2 – own transport capacity is in line with average volume of delivery; W_3 – own transport capacity is in line with minimal volume of delivery; W_4 – company works without own transport, but buys transportation services; τ – period of time; τ_{Qmax} – period of time with the maximal level of demand for delivery.

Usually the level of the demand for delivery is unstable for a particular company: it fluctuates depending on different factors such as season, days of the week etc. The use of one's own transport capacity is described with lines: W_1 (in line with maximal volume of delivery); W_2 (in line with average volume of delivery); W_3 (in line with minimal volume of delivery) and W_4 (without own transport). If the company chooses its own transport capacity W_1, then it is fully loaded only for the period τ_{Qmax}., but other periods provide idle time and additional expenses. It is possible to decrease vehicle idle time and choose one's own transport capacity W_2; in this case additional expenses occur whenever $W_2>Q$. Seemingly, the optimal strategy provides one's own transport capacity W_3, when company vehicles are loaded all the time and work without idle time. If $Q>W_3$, it is necessary to involve also the forwarder transport service creating one's own vehicles and commercial service combined [5].

This approach provides the optimal result because it allows minimizing the transportation costs, working without vehicle idle time as well as providing high delivery quality level for customers. Manufacturers and trading companies may use it to control physical distribution of small cargo.

It is necessary to notice some principles to create efficient circular route:

1. Group customers and solve which vehicle serves the particular group.
2. Create water drop shape route.
3. Do not allow two or more routes crossing.

4. Create routes depending on the customers' demand per days of the week.
5. If customer is located outside the group, it is expedient to create pendulum route or use forwarder service.
6. If a company has vehicles with different level of capacity, first of all use biggest capacity vehicles (if the time-factor allows it). If the time factor is the main one, it is necessary to decrease a number of objects for one route.
7. Investigate acceptance of good time period for each customer.

In Latvia there are many trading companies, whose basic customers are located in the capital (Riga) or a city. The situation is similar in other countries, too. In this case, it is expedient to use the following principle to combine own transport and transportation services.

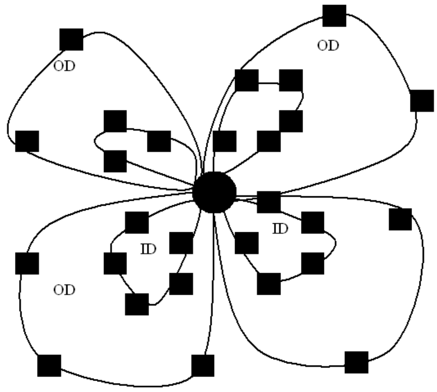

Fig. 2. **Physical distribution control, using "drops" system:**
● – trading company or manufacturer (base) located in city; ■ – customers (objects);
ID – "inland" drop; *OD* – "outward" drop

Figure 2 describes the "drops" system approach for physical distribution control. It is expedient to divide customers into 2 groups – "inland"(for example, customers located in the city) and "outland" (customers located outside the city) drops.

The best concentration of customers is not far from the trading company, but outside city customers scattered in a large territory of the state. In this case it is possible to control physical distribution, using the following steps:

- Create "drops" route system;
- Calculate the optimal radius – distance from the base, where own transport is used with minimal costs. Find the "border", where it is inexpedient to serve customers by one's own vehicles.
- Choose own vehicles to serve "inland" drop customers, use forwarders transportation services to serve "outward" drop customers (Figure 2).

Often the number of customers in the city is bigger than outside the city (Figure 2).

This method has many advantages:

- company serves its best or basic customers by its own vehicles;
- company may provide a high delivery quality level, serving its main customers by its own vehicles;
- using the micro-elements method, the company may provide accurate deliveries also for cities with intensive or unstable traffic.
- this approach is cheaper than using commercial transport services only, due to the fact that the forwarder service for a small distance is very expensive.

The vehicle unloading time also influences the total time of delivery. Usually it is difficult to register this element of the delivery time because vehicles waiting (in a queue) time may vary for each customer depending on the particular hours of a day. It is essential to divide the total unloading time into separated micro-elements, as well as to create the waiting time database in order to optimize the unloading time control process for local deliveries.

The optimal radius to serve objects by own vehicles

It is significant to calculate the optimal or marginal distance from the base to serve a customer by one's own transport. Often, especially in big cities, it is difficult to solve this problem to optimize the company delivery system.

Usually there are many different variants to serve trading company customers. If the manager increases the serving radius, the number of customers also increases (Figure 3). It is possible to increase it more, and the number of customers increases again (*R3*, Figure 3). The optimal radius provides the company the best profit, serving customers by its own transport:

$$\pi = TR - TC. \tag{2}$$

Generally, increasing of business radius also increases number of customers and *TR* as well. But delivery costs also rise. In this case, it is expedient to find the best radius, which provide the biggest difference between *TR* and *TC* rates.

In practical conditions it is possible to find the optimal radius for delivery with one's own transport; it conforms to the situation where:

$$MC = AC, \tag{3}$$

where: *MC* – marginal costs;
AC – average costs.

Basically, the optimal distance should provide the maximal profit, serving customers from the base by one's own transport.

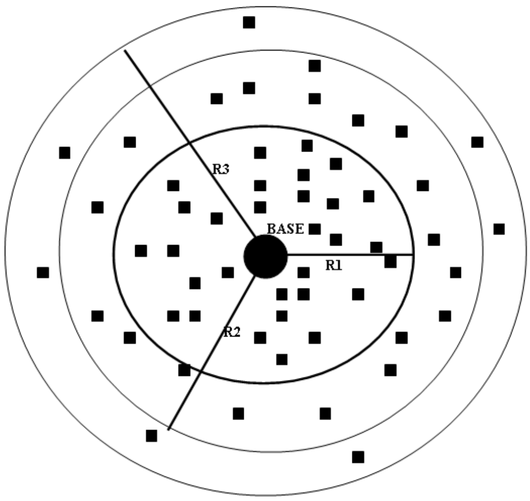

Fig. 3. **The optimal radius for delivery with own transport:**
● – trading company or manufacturer (base) located in city; ■ – customers (objects); *R1* – shortest radius from the base; *R2* – average radius from the base; *R3* – biggest radius from the base

Figure 3 provides information about interconnection between the number of customers and opportunities of radius to serve customers.

R1 – the shortest radius from the base (usually includes customers located in the city) – in this case the company has a particular number of customers and their geographical location concentration is high. If we increase the serving radius (*R2*), also the number of customers increases, but their geographical location concentration is not so high in comparing with the next radius R1. The number of the served objects increases by some units if we choose *R3* radius but their geographical location concentration is very low.

Often it is not expedient to serve these objects, because the total revenue increases more slowly than the total costs; consequently the profit of the company decreases.

Example.

A company has 9 opportunities to serve customers by its own transport. It is necessary to choose the optimal radius (with the maximal profit) to serve objects if the dynamics of growth of *TR* is known for each radius. The costs for the company (fixed costs, variable costs, average costs, marginal costs, total costs) as well as the revenue and other rates are described in Table 2.

Table 2

Fixed, Variable, Total, Marginal and Average costs, LVL

Number of alternative (*n*)	**Radius from the base, distance (*l*), km**	**Volume of demand (*q*), units**	***FC***	***VC***	***TC***	***V AVC***	***C ATC***	***MC***
1	10	60	200	230	430	23.0	43.0	43.0
2	20	140	200	330	530	16.5	26.5	10.0
3	30	228	200	450	650	15.0	21.6	12.0
4	40	336	200	580	780	14.5	19.5	13.0
5	50	450	200	725	925	14.5	18.4	14.5
6	60	600	200	880	1080	14.6	18.0	15.5
7	70	700	200	1060	1260	15.1	18.0	18.0
8	80	768	200	1260	1460	15.7	18.2	20.0
9	90	819	200	1470	1670	16.3	18.5	21.0

Table 2 provides information about a company which has 9 opportunities to serve customers by its own transport. The second and third columns describe changes of the volume of demand (third column) depending on the changes of the serving radius (second column). If the radius increases, the number of served customers and volume of demand increase as well. The fixed costs (fourth column) are stable for all opportunities, but the variable costs (fifth column) change. *AVC* and *ATC* change depending on the serving radius and volume of demand.

Marginal costs (*MC*) may be calculated, using the following formula [6]:

$$MC = \frac{TC_n - TC_{n-1}}{l_n - l_{n-1}} \tag{4}$$

where: l_n – delivery radius, for instance, if n=2:

$$MC = \frac{TC_n - TC_{n-1}}{l_n - l_{n-1}} = \frac{530 - 430}{30 - 20} = 10.$$

If the customer serving radius is increasing, *TC* also increases.

Table 3

Total Costs and Total Revenue. Marginal Costs and Marginal Revenue, LVL

Distance (*l*), km	**Volume of demand (*q*), units**	**Price per unit**	***TR***	***MR***	***VC***	***AC***	***TC***	***MC***	**Profit (+), losses (–)**
10	60	2.60	156.0	15.6	23.0	43.0	430	43.0	–274.0
20	140	2.50	350.0	19.40	16.5	26.5	530	10.0	–180.0
30	228	2.40	547.2	19.70	15.0	21.6	650	12.0	–102.8
40	336	2.30	772.8	22.50	14.5	19.5	780	13.0	–7.8
50	450	2.20	990.0	21.70	14.5	18.4	925	14.5	+70.0
60	**600**	**2.08**	**1248.0**	**25.80**	**14.6**	**18.0**	**1080**	**15.5**	**+168.0**
70	**700**	**2.04**	**1428.0**	**18.00**	**15.1**	**18.0**	**1260**	**18.0**	**+168.0**
80	768	2.00	1536.0	10.80	15.7	18.2	1460	20.0	+76.0
90	819	1.90	1556.1	2.01	16.3	18.5	1670	20.1	–113.9

Table 3 provides information about the profit or losses for different radiuses of delivery. For instance, a radius 10 km is not optimal, because *MC* is not equal to *AC* and the company has losses – 274 (last column) monetary units. The best radius will be a distance 60-70 km from the base, because, for 70 km radius:

1. $MC=AC=18$ monetary units
2. It is profit +168 monetary units.

If the company continue to increase its business radius of delivery, the profit will decrease (+76 monetary units for 80 km radius; –113.9 monetary units for 90 km radius).

Conclusions

1. There are different ways to solve some physical distribution problems, connected with the accuracy factor, time factor and costs. Is it significant to choose between own transport or commercial transportation services; to find what the best combination of these solutions is.
2. Usually the best variant is when own transport is fully loaded. If the demand increases, it is possible to buy additional transportation services from transport company or forwarder. This approach allows providing high quality deliveries and reduces transportation costs as well.
3. The optimal radius or delivery distance provides the maximal profit for the company. It is necessary to make cost analysis and find the best radius, when $AC=MC$.

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