APPLICATION OF CLARKE-WRIGHT METHOD FOR SOLVING ROUTING PROBLEM IN DISTRIBUTION LOGISTICS

Eva MAJERČÁKOVÁ, Peter MAJERČÁK

1 Introduction

One of the basic activities of enterprise logistics is distribution, production planning, providing of materials and raw materials for production and warehousing. It is appropriate to focus on distribution logistics, which is not always given sufficient attention. Due to the fact, that every enterprise has different distribution logistics, it can be stated, that distribution logistics is very diverse. Within the distribution, an enterprise can make some changes, which can also lead to an inappropriate solution, it means to a disproportionate increase in logistics costs. One of the ways, how to make positive changes, is finding optimal solution of routing transport. One of the methods, which is dealing with optimal routing, is Clarke-Wright method.

2 Distribution logistics – part of the marketing logistics

"Distribution logistics represents connecting link between the production and marketing part of the enterprise. It includes all the warehousing and transportation movements of goods for purchaser (customer) and associated information, management and control activities. The aim here is to make available the right product at the right time to the right place in the right quantity and quality and at the same time to create an optimal ratio between a specific set of supplied services, which the enterprise is able to provide (or customers directly required) and emerging costs" [5].

Veľká ekonomická encyklopédia states that: "Distribution logistics; part of marketing logistics; Includes all activities, which are necessary in order to continuously get a product from the production site to the last point in the distribution channel. These activities consist of: planning and deployment of warehouses; warehousing; transport; packaging; order fulfillment. The role of distribution logistics of enterprise is to get the right product at the right time to the right place at minimal cost. System of distribution logistics generally consists of four functional parts: input
"Distribution logistics has thus solves only a certain segment of certain circulatory process, as one of a part of marketing policy" [8].

Distribution logistics is an integral part of the logistics chain. From the above definitions follow, that it is that part of logistics, which begins at the moment of supply of the finished product to the warehouse of finished products, continues subsequent process and ends product supply to the final customer (consumer). Customers (consumers) are trying to have minimum stocks and therefore prefer individual orders in smaller quantities and at frequent intervals. Suppliers are so forced to choose efficient and effective distribution strategy.

Main objectives of distribution logistics are:

- optimizing the number of distribution warehouses,
- increase flexibility,
- reduce binding of capital,
- efficiently handle with materials (management of packaging)
- focus on short transportation times,
- quick and actual providing information,
- effective system of orders fulfillment,
- quality management systems,
- high level of services.

2.1 Distribution channel

Only a small number of products gets a direct route to the final customer. While the product is supplied to the final customer, it is necessary to include the whole range of logistics activities. It leads to the formation of the distribution channel.

Distribution channel can be divided into nodes and stretches. Nodes are in this case the organizational units, which are involved in the distribution of products. After the stretches are the products moved between nodes. Distribution channel begins at the producer and ends at the final customer.

The structure of distribution channels can be divided according to different parameters [2]:

- *the length of the distribution*, i.e. *the number of distribution degrees*, through which the product gets from the producer to the final customer,
• *extent of the distribution*, i.e. the number of distributors who participate on the distribution on given degree of distribution,

• *kind of distributors*.

The most common connections of the producer with the final customer can be shown in Fig. 1 [7].

*Fig. 1 The most common connections of the producer with the final customer*

Source: authors according to [7]

Based on the above parameters, the distribution channel can be divided as follows:

According to *the length of the distribution*, i.e. according to *the number of distribution degrees*, divided distribution as follows [2]:

- direct distribution,
- indirect (gradual) distribution,
- combined distribution.

*Direct distribution* uses only one distribution degree, i.e. the product is supplied from the producer to the final customer *directly*, without the agent.

*Indirect (gradual) distribution* is used more frequently. The product is supplied to the final customer *indirectly (gradual)*, i.e. through the several degrees.

For *the combined distribution* is considered, when the enterprise uses for a certain part of its production direct distribution and for other production uses indirect distribution.

The suitability of use, the advantages and disadvantages of direct and indirect distribution are shown in Fig. 2.
Fig. 2 The suitability of use, advantages and disadvantages of direct and indirect distribution

<table>
<thead>
<tr>
<th>Direct distribution</th>
<th>Suitable for:</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>- a small number of customers,</td>
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<tr>
<td></td>
<td>- distribution for short distances,</td>
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<tr>
<td></td>
<td>- stage of introduction of new products on the market,</td>
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<td></td>
<td>- products with a short sustainability on the market.</td>
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<table>
<thead>
<tr>
<th>Advantages:</th>
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<tbody>
<tr>
<td>- direct contact of producer with customers (direct information)</td>
</tr>
<tr>
<td>- direct control of distribution,</td>
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<tr>
<td>- quick response to changes in requirements on the customer side.</td>
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<table>
<thead>
<tr>
<th>Disadvantages:</th>
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<tbody>
<tr>
<td>- high level of stocks in production warehouses,</td>
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<tr>
<td>- high transport and distribution costs.</td>
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</table>

<table>
<thead>
<tr>
<th>Indirect (gradual) distribution</th>
<th>Suitable for:</th>
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<tbody>
<tr>
<td></td>
<td>- a large number of customers,</td>
</tr>
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<td></td>
<td>- sale associated with high requirements for service,</td>
</tr>
<tr>
<td></td>
<td>- products of long durability.</td>
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<table>
<thead>
<tr>
<th>Advantages:</th>
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<tbody>
<tr>
<td>- lower need of stocks in production warehouses,</td>
</tr>
<tr>
<td>- shorter delivery time for the customer,</td>
</tr>
<tr>
<td>- lower transport and distribution costs,</td>
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<tr>
<td>- easier administration.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Disadvantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- loss of direct contact with customers,</td>
</tr>
<tr>
<td>- indirect information and control of distribution</td>
</tr>
<tr>
<td>- slower response to changes in customer requirements.</td>
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</tbody>
</table>

Source: authors according to [1]

According to the distribution range, i.e. according to the number of distributors, distribution divided as follows [2]:

- extensive distribution,
- selective distribution,
- exclusive distribution.

The main criterion for selecting these forms is the frequency of sale.

In extensive distribution is interest of producers or distributors, that their products are available to the customers, at all sales areas, or in all stores of the same type, or in all stores in the given region, etc.

In the case of selective distribution the product is sold and distributed only to selected types of stores (one of the reasons could be requiring high qualifications of the seller).
Form of **exclusive distribution** is used in the case of sale of very expensive products, which are exceptional and are intended for a narrow group of customers. To this fact must also correspond the sales environment, staff and high level of services [3].

Suitability for use, advantages and disadvantages of extensive, selective and exclusive distribution are shown in Fig. 3.

**Fig. 3 Suitability for use, advantages and disadvantages of extensive, selective and exclusive distribution**

<table>
<thead>
<tr>
<th>Extensive distribution</th>
<th>Selective distribution</th>
<th>Exclusive distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Suitable for:</strong></td>
<td><strong>Suitable for:</strong></td>
<td><strong>Suitable for:</strong></td>
</tr>
<tr>
<td>- everyday products,</td>
<td>- rarely purchased products,</td>
<td>- a narrow range of customers,</td>
</tr>
<tr>
<td>- products with minimum</td>
<td>- products with higher</td>
<td>- products requiring special</td>
</tr>
<tr>
<td>requirements for service.</td>
<td>requirements for service.</td>
<td>sales environment, trained</td>
</tr>
<tr>
<td></td>
<td></td>
<td>staff, etc.</td>
</tr>
<tr>
<td><strong>Advantages:</strong></td>
<td><strong>Advantages:</strong></td>
<td><strong>Advantages:</strong></td>
</tr>
<tr>
<td>- products are available to a large range of customers.</td>
<td>- easier distribution,</td>
<td>- very close contact with customers.</td>
</tr>
<tr>
<td></td>
<td>- provide a higher level of services,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- higher culture of sale.</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages:</strong></td>
<td><strong>Disadvantages:</strong></td>
<td><strong>Disadvantages:</strong></td>
</tr>
<tr>
<td>- high demands on the distribution,</td>
<td>- products are available in limited quantities,</td>
<td>- products are available to a narrow range of customers.</td>
</tr>
<tr>
<td>- limited opportunities to provide higher level of services.</td>
<td>- the need to look for methods for customer acquisition.</td>
<td></td>
</tr>
</tbody>
</table>

Source: authors according to [1]

According to **the kind of distributors** can be divided the structure of distribution channels into wholesales, wholesales with a network of retail stores, sales according to samples, agents etc.

### 3 Application of Clarke-Wright method for solving routing problem

There are the number of heuristic methods, by which it is possible to solve the role of routing. The best known heuristic method, which solves the problem of vehicle route (VRP - Vehicle Routing Problem), is Clarke-Wright method. Solving the role of routing by Clarke-Wright method is carried out by gradual steps. First, it is found the
least preferred solution, which is then improved by each gradual steps. Thanks to solution by gradual steps can be monitored and controlled defined conditions. The whole procedure for solving the role of routing (formulation the role of routing including defined conditions of admissibility, procedure of method and procedure for solving the role with all steps) is taken over according to [4] as follows:

The role of routing is generally formulated on the transport network of $S - (V; H)$, where $V$ is the set of nodes of the network, and $H$ is the set of edges connecting these nodes. Node $V_0$ represents wholesale warehouse of given transport network, nodes $V_1, \ldots, V_n$ are delivery points (points requiring manual). Each delivery point has certain requirement for transport of certain quantities per transport elements. Transport is carried out by means of vehicles, whose route starts and ends in the node $V_0$ and their capacity is limited. The objective is to compile sets of routes vehicles so, that must be satisfied the requirement of each delivery point only with one ride of vehicle. The total transport costs must be minimal.

Based on the above, are set out two basic conditions of admissibility of solution:

1) each customer must be served only once (within one route)
2) must not be exceeded capacity of serving vehicles.

Other restrictive conditions of admissibility of solution can be:

- limit the maximum duration, i.e. length of one route,
- restricted disposable rolling stock,
- restriction resulting from the maximum number of served points by one route (relative to their needs and capacities of vehicles),
- respect for time reachability of served points (satisfaction of requirement of served points in the certain time interval),
- respect for technical reachability of served points (the customer is served only with a vehicle of a particular specification),
- limited fuel consumption.

Procedure for method is, that it is first prepared starting (acceptable), but inefficient solution, which is formed by the selection of two possible routes ($V_0 - V_i - V_0$) and ($V_0 - V_j - V_0$). These two routes are then connected in one so-called pooled route ($V_0 - V_i - V_j - V_0$). Two routes can be connected into one (pooled) route only if the resulting pooled route meets the above conditions of admissibility of solution (1) and (2). It follows, that the sum of load of pooled routes must not exceed the capacity of the vehicle $K$. 
Advantage or disadvantage of pooling of the two routes is determined by saving generated by pooling. This saving is measured so-called coefficient of advantage \( z_{ij} \) as:

\[
z_{ij} = (d_{0i} + d_{0j} - d_{ij})
\]  

(1)

where \( d_{0i}, d_{0j} \) and \( d_{ij} \) indicate the length of the edges \((V_i, V_0), (V_0, V_j)\) and \((V_i, V_j)\).

It follows, that the value \( z_{ij} \) expresses the difference between the sum of lengths of routes \((V_0 \rightarrow V_i \rightarrow V_0)\) and \((V_0 \rightarrow V_j \rightarrow V_0)\) and the length of pooled route \((V_0 \rightarrow V_i \rightarrow V_j \rightarrow V_0)\). By this method, in each iteration of procedure are pooled this two nodes, that have the highest coefficient of advantage \( z_{ij} \), if this pooling can be carried out (respect to the conditions of admissibility). The advantage of this procedure is, that the coefficient \( z_{ij} \) depends only on the mutual distances of nodes \( V_i, V_j, \) and \( V_0 \) and is fixed, if it is possible pooling of this two nodes.

Procedure for solving the role can be formulated in several steps:

1. For a given transport network is necessary to compile the distance matrix:

\[
D = \{d_{ij}\}
\]

(2)

where \( i, j = 0,1,...,n, n = |V| \)

Other values, that is necessary to know, are:

- \( c \) .................................. the average speed of the vehicle on the network
- \( t \) .................................. the time required to unload the unit amount of elements from serving vehicle
- \( T \) .................................. maximum duration of vehicle stay outside the starting node \( V_0 \)
- \( K \) .................................. vehicle capacity
- \( q_i \) .......................... a number of transported elements from node \( V_0 \) to node \( V_i \)  
  \((i = 1,2,...,n)\)

2. It is drawn up the initial solution of role (Fig. 4). The solution includes a set of elementary routes \((V_0 \rightarrow V_i \rightarrow V_0)\) for all network nodes \( i = 1,2,...,n \), with given number of elements and delivery time.
From the matrix $D$ derives the matrix of coefficients of advantages $Z = \{z_{ij}\}$, where $i, j = 1, \ldots, n$ according to equation (1), i.e. $z_{ij} = (d_{0i} + d_{0j} - d_{ij})$, where $z_{ij}$ expresses the difference between the sum of lengths of routes $(V_0 \rightarrow V_i \rightarrow V_0)$ and $(V_0 \rightarrow V_j \rightarrow V0)$ and the length of pooled route $(V_0 \rightarrow V_i \rightarrow V_j \rightarrow V_0)$.

2. In the matrix $Z$ is found the biggest positive element $z_{ij}$ and routes $(V_0 \rightarrow V_i \rightarrow V_0)$ and $(V_0 \rightarrow V_j \rightarrow V_0)$ are connected (if it is possible) to the pooled route $(V_0 \rightarrow V_i \rightarrow V_j \rightarrow V_0)$. If such element does not exist, so the result of the algorithm is the actual set of vehicle routes. If such element exists, goes to step 5.

3. Check, if is formed by connecting routes $(V_0 \rightarrow V_i \rightarrow V_0)$ and $(V_0 \rightarrow V_j \rightarrow V0)$ the admissible route. If such route is not formed, so $z_{ij} = 0$ and goes to step 4. If such route is formed, so goes to step 6.

4. Updating the set of nodes $V$ by selecting of nodes $i$ and $j$, if by pooling routes ceased to be ultimate nodes of route. It is put $z_{ij} = 0$. Updating the set of routes by selecting of pooled routes and is formed new route. At the same time are also updating other monitored parameters (delivery time, length of the route).

If the step 4. and 5. is not possible, it is necessary to find the nearest smaller or the same size element $z_{st}$ and are pooled routes, which include nodes $V_s$ and $V_t$; it can be elementary routes or routes, which was formed by previous pooling. For ultimate nodes $V_s$ and $V_t$ newly formed route is put $z_{ij} = 0$ and goes to step 4.

The whole procedure is repeated as long as the matrix $Z$ is not exhausted or until it is not clear, that the capacity of vehicles are exhausted and another solution is meaningless.

### Table: Initial solution of role

<table>
<thead>
<tr>
<th>Route</th>
<th>Number of elements</th>
<th>Delivery time</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_0 \rightarrow V_i \rightarrow V_0$</td>
<td>$q_1$</td>
<td>$\frac{2 \cdot d_{01}}{c} + t \cdot q_1$</td>
</tr>
<tr>
<td>$\ldots$</td>
<td>$\ldots$</td>
<td>$\ldots$</td>
</tr>
<tr>
<td>$V_0 \rightarrow V_n \rightarrow V_0$</td>
<td>$q_n$</td>
<td>$\frac{2 \cdot d_{0n}}{c} + t \cdot q_n$</td>
</tr>
</tbody>
</table>

Source: [4]
4 Conclusion

The priority of enterprise is to provide complex services to customers. Complexity of services (in addition to itself purchase of products) means also transport of products to the final customer. On the distribution of products, which is directed from producer to the final customer directly or indirectly (gradual through the several distribution degrees), high demands are placed. The objective of this article, was acquainted with the problems of distribution logistics. Were explained the basic terms used in the literature, for example distribution logistics or distribution channel including its breakdown by certain parameters. Based on the above, was from a number of heuristic methods chosen and described in detail Clarke-Wright method, by which it is possible to solve the routing role. The whole procedure of method is described in detail in the article.

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References


Resume

Distribution logistics is an inseparable part of the logistics chain. It starts at the moment of supply of the finished product to the warehouse of finished products and ends at the moment of supply of the finished product to the final customer. To the final customer is by direct way supplied only a minimal amount of products. Much more common is, that the product is supplied to the customer indirectly through several distribution degrees. While the product is supplied to the final customer, it is necessary to encompass a whole range of logistics activities. The objective of article is to highlight the possibility of solving the problem of routing according to Clarke-Wright method. It is one of a large number of heuristic methods, which solves the problem of vehicle routing.

Keywords

Distribution logistics, distribution channel, Clarke-Wright method, route

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