Application of Clark and Wright´s Savings Algorithm Model to Solve Routing Problem in Supply Logistics

Clark Wright algoritam modela uštede koji se koristi kod rješavanja problema usmjeravanja u logistici opskrbe

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Summary

Distribution logistics is an inseparable part of a logistics chain. It starts at the moment of a finished product supply to a warehouse of finished products and ends at the moment of its delivery to a final customer. Only a minimal amount of products is supplied directly to the final customer. It is more common to supply the product to the customer indirectly using 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 the article is to highlight the possibility of solving the problem of routing according to Clarke-Wright´s method. It is one of a large number of heuristic methods which solves the problem of vehicle routing.

KEY WORDS

Clark-Wright method
distribution logistics
supply
vehicle routing

Sažetak

Logistika distribucije je neodvojiv dio lanca logistike. Počinje trenutkom opskrbe gotovog proizvoda do skladišta gotovog proizvoda i završava trenutkom dostave gotovog proizvoda krajnjem kupcu. Krajnjem kupcu se dostavlja samo minimalna količina proizvoda. Uobičajenije je da se proizvod dostavi kupcu indirektno kroz različite stupnjeve distribucije. Dok se proizvod dostavlja krajnjem kupcu,potrebno je obuhvatiti cijeli spektar logističkih aktivnosti. Cilj ovog članaka je naglasiti mogućnost rješavanja problema usmjeravanja prema Clarke.Wright metodi. To je jedna od velikog broja heurističkih metoda koje rješavaju problem usmjeravanja kopnenih vozila.

KLJUČNE RIJEČI

clark-wright metoda
logistika raspodjele
opskrba
usmjeravanje vozila

1. INTRODUCTION

To the basic activities of enterprise logistics belong 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 a 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 to find an optimal solution of routing transport. One of the methods, which is dealing with the optimal routing, is Clarke-Wright´s method. In many distribution systems, routing vehicles are very important to service customers. In fact, many companies are faced with problems regarding the transportation of people, goods or information. Transportation costs typically range between one third and two thirds of total logistic costs; improvement of efficiency through the maximum utilization of transportation equipment and personnel is a major concern. These companies have to optimize transportation by using rational manners and effective tools.

The Vehicle Routing Problem (VRP) plays a central role in the fields of physical distribution and logistics and involves the design of a minimum cost delivery route, starting and terminating at a depot which services a set of customers. VRP is an important and difficult combinatorial optimization problem which requires the determination of an optimal set of routes employed by a fleet of vehicles to serve a set of customers, taking various operational constraints into account. Each customer must be supplied exactly once by one vehicle route. The total demand of any route must not exceed the vehicle capacity. The total length of any route must not exceed a pre-specified bound.

The Vehicle Routing Problem with Time Window (VRPTW) has recently received an attention of the research community. VRPTW is an extension of the VRP that addresses not only the spatial but also the temporal aspect of a vehicle movement. The objective is to design optimal routes that satisfy all constraints. VRPTW involves finding the best routing schedule for a fleet of homogenous (or heterogeneous) vehicles starting and terminating at a central depot with limited capacities and associated with maximum travel time to service a set of customers with known demand and time window characterized by the earliest and the latest allowable time within which the service should begin. Clarke and Wright´s savings approach stands out over the other methods as it is flexible enough to handle a wide range of practical constraints, it has relatively fast computation of problems with a moderate number of stops and it is also capable of generating solutions that are nearly optimum. The comparison of optimal results for small problems with a limited number of constraints shows that the savings approach gives solutions that are, on average, 2.5 per cent over the optimum for asymmetric distance meanwhile the nearest neighbour 8.5 per cent over the optimum [1-5].

2. DISTRIBUTION LOGISTICS – PART OF THE MARKETING LOGISTICS

"Distribution logistics represents a connecting link between the production and marketing part of the enterprise. It includes all the warehousing and transportation movements of goods to purchasers (customers) and associated information, management and control activities. The aim is to make the right product available at the right time, in 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 require directly) and emerging costs" [5].

Veľká ekonomická encyklopédia states that: *"Distribution logistics, a part of marketing logistics, includes all activities which are necessary to get a product continuously from the production site to the last point in the distribution channel. These activities consist of: planning and deployment of warehouse, warehousing, transport, packaging, order fulfilment. The role of distribution logistics of enterprise is to get the right product at the right time to the right place at minimal costs. The system of distribution logistics generally consists of four functional parts: input (functional activities), process, output (objectives of distribution logistics) and feedback (information flow)"* [6].

"Distribution logistics thus solves only a certain segment of a certain circulatory process, as one of the part of a marketing policy" [6-8].

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

Main objectives of distribution logistics are:

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

2.1. Distribution Channel

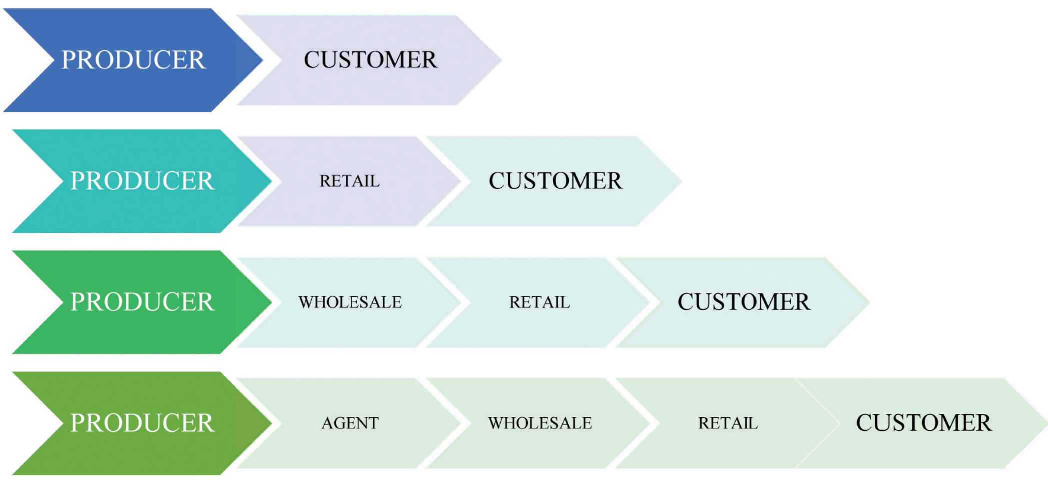
Only a small number of products gets a direct route to the final customer. While the product is supplied to the final customer, it is necessary to include the whole range of logistics activities. It leads to the formation of a distribution channel.

The 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. Stretches are the products moving between the nodes. The 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]:

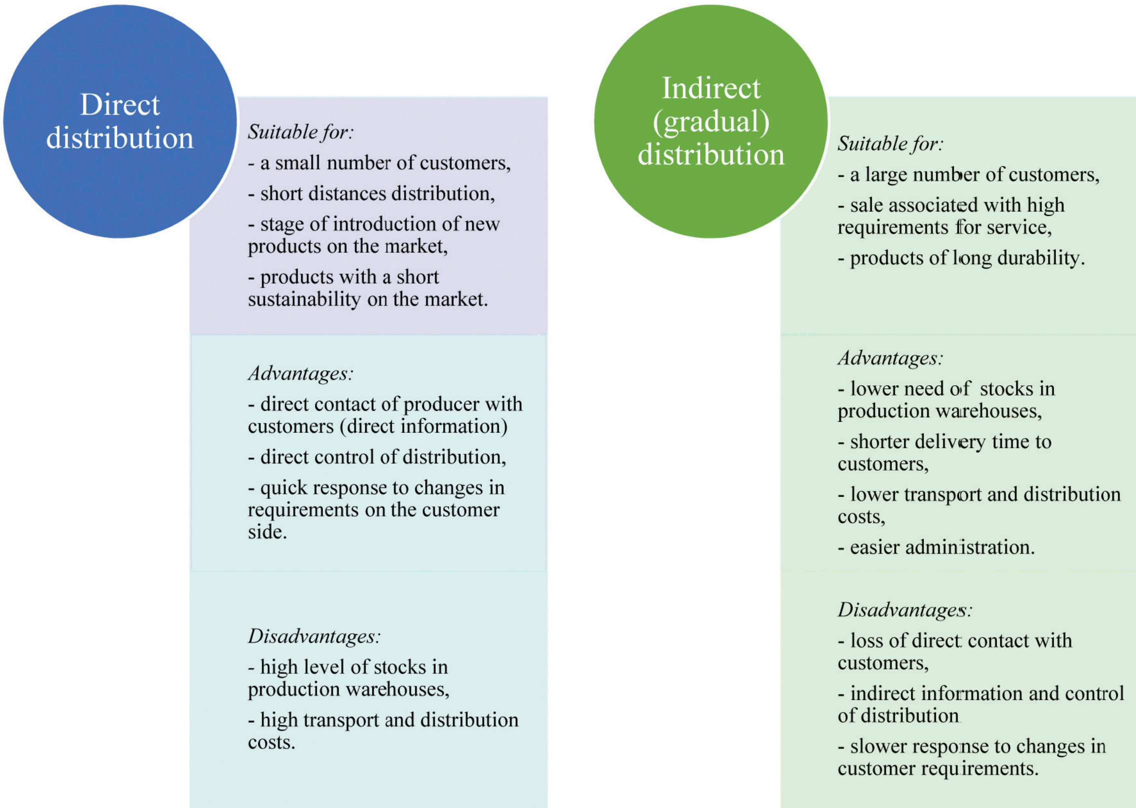
- *the length of the distribution, i.e. the number of distribution degrees*, through which the product gets from the producer to the final customer,
- *extent of the distribution*, i.e. the number of distributors who participate in the distribution on a given degree of distribution,
- *kind of distributors*.

The most common connections of the producers with the final customer are shown in Figure 1 [7].



Source: authors according to [7]

Figure 1 The most common connections of the producer with the final customer



Source: authors according to [1]

Figure 2 Suitability of use, advantages and disadvantages of direct and indirect distribution

Based on the above mentioned 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 [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. using several degrees.

When the enterprise uses a direct distribution for a certain part of its production and indirect distribution for another, it is typical of the combined distribution.

The suitability of the use, advantages and disadvantages of direct and indirect distributions are depicted in Figure 2.

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

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

The main criterion of this classification is the frequency of sale.

In extensive distribution, the interest of producers or distributors is to make their products available to the customers in 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 the requirement of high qualification skills of the seller).

The 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. Sales environment, staff and high level of services have to correspondent to this fact [3].

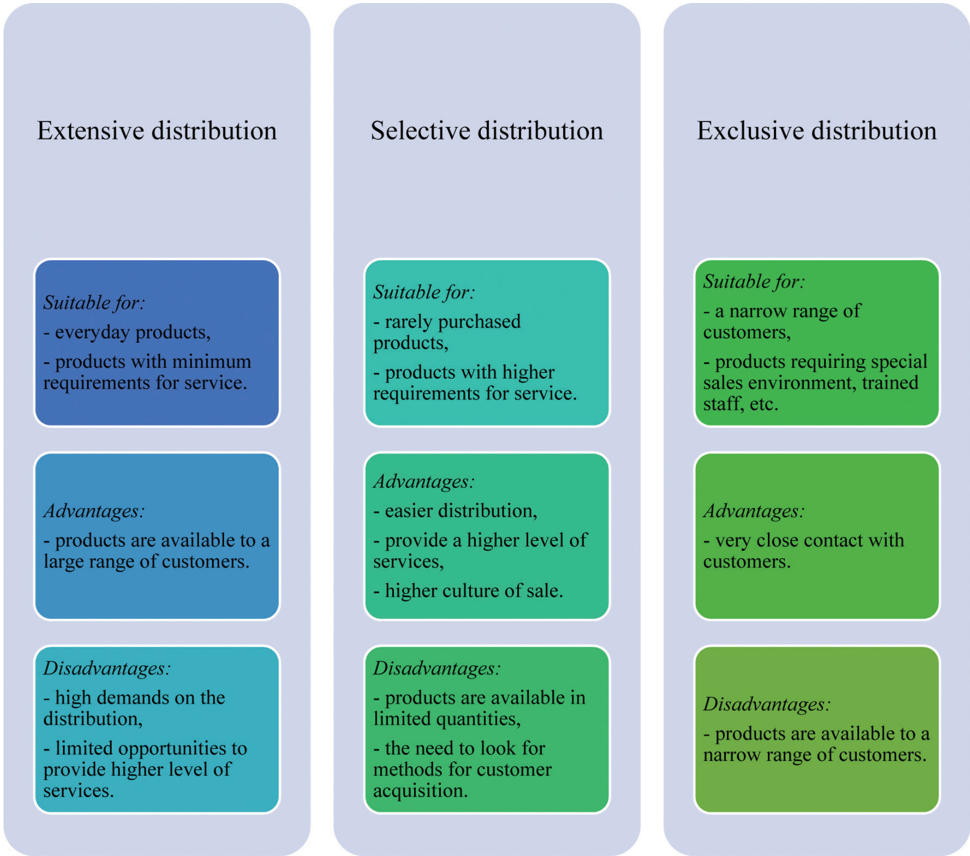
The suitability of use, advantages and disadvantages of extensive, selective and exclusive distributions are shown in Figure 3.

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

3. APPLICATION OF CLARKE-WRIGHT´S *METHOD TO SOLVE* ROUTING PROBLEMS

There is a number of heuristic methods which are used to solve the role of routing. The best known heuristic method, which solves the problem of vehicle routing (VRP - Vehicle Routing Problem), is Clarke-Wright´s method. Solving the role of routing by Clarke-Wright´s method is carried out by gradual steps. Firstly, the least preferred solution, which is then improved by each gradual step, is found. Thanks to this solution, defined conditions can be monitored and controlled by gradual steps. The whole procedure of solving the role of routing (formulation of the role of routing including defined conditions of admissibility, procedure of methodology and of solving the role using 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 a wholesale warehouse of a given transport network, nodes $V_1, \ldots, V_N$ are delivery points (points requiring manual). Each delivery point has a certain requirement for the transport



Source: authors according to [1]

Figure 3 Suitability of use, advantages and disadvantages of extensive, selective and exclusive distribution

of certain quantities per transport elements. Transport is carried out by means of vehicles, their route starts and ends in the node V_0 and their capacity is limited. The objective is to compile sets of routes for vehicles to fulfil the requirement that each delivery point is satisfied only with one ride of the vehicle. The total transport costs must be minimal.

Based on the above, two basic conditions of the solution admissibility may be defined [1], [3]:

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

Other restrictive conditions can be:

- limitation of the maximum duration, i.e. the length of one route,
- restricted disposable rolling stock,
- restriction resulting from the maximum number of points served by one route (relative to the 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 of the method, that it is the first prepared starting (acceptable), but inefficient solution, 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 into 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 two routes is determined by savings generated by pooling. This saving is measured by so-called coefficient of advantage *zij* as:

$$z_{ij} = (d_{0i} + d_{0j} - d_{ij}) \tag{1}$$

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 ($V_0 – V_i - V_0$) and ($V_0 – V_j - V_0$) and the length of pooled route ($V_0 - V_i - V_j - V_0$). The specification of the method is that in each iteration of procedure are pooled those two nodes that have the highest coefficient of advantage z_{ij}, if this pooling can be carried out (with 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 it is fixed, if it is a possible pooling of these two nodes.

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

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

$$D = \{d(i;j)\} \tag{2}$$

where $i, j = 0,1, \ldots\ldots\ldots n,$
$n = / V /.$

Other values, that are necessary to know, are:

- c………an average speed of the vehicle on the network,
- t………time required to unload the unit amount of elements from serving vehicle,
- T………maximum duration of a 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. The initial solution of the role is drawn up (Figure 4). The solution includes a set of elementary routes ($V_0 - V_i - V_0$) for all network nodes i = 1, 2, …, n with a given number of elements and delivery time.

Route	Number of elements	Delivery time
$V_0 - V_i - V_0$	q_1	
………	………	………
$V_0 - V_n - V_0$	q_n	

Source: [4]

Figure 4 Initial solution of the role

3. Matrix D is used to derive the matrix of coefficients of advantages $Z = \{z_{ij}\}$, where $i, j = 1, ...$ 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 ($V_0 - V_i - V_0$) and ($V_0 - V_j - V_0$) and the length of the pooled route ($V_0 - V_i - V_j - V_0$).
4. The biggest positive element z_{ij} is found in the matrix Z and routes ($V_0 - V_i - V_0$) and ($V_0 - V_j - V_0$) are connected (if it is possible) to the pooled route ($V_0 - V_i - V_j - V_0$). If such an element does not exist, so the result of the algorithm is the actual set of vehicle routes. If such an element exists, go to step 5.
5. Check, if the admissible route is formed by connecting the routes ($V_0 - V_i - V_0$) and ($V_0 - V_j - V_0$). If such a route is not formed, so $z_{ij} = 0$ and go to step 4. If such a route is formed, go to step 6.
6. Update the set of nodes V by the selection of nodes i and j, if the pooling routes cease to be ultimate nodes of route. The condition is $z_{ij} = 0$. Updating the set of routes by the selection of pooled routes helps form a new route. At the same time other monitored parameters (delivery time, length of the route) are also updated.

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

The whole procedure is repeated as long as the matrix Z is not exhausted or until it is clear, that the capacities of vehicles are exhausted and another solution is meaningless [2-4], [9-12].

4. CONCLUSION

The priority of any enterprise is to provide complex services to customers. Complexity of services (in addition to purchase of own products) means also the transport of products to the final customer. High demands are placed on the distribution of products, which is directed from producer to the final customer directly or indirectly. The objective of this article was to get acquainted with the problems of distribution logistics. The basic terms used in the literature, for example distribution logistics or distribution channel including its classification by certain parameters, were explained. From a number of heuristic methods, Clarke-Wright´s method, which is possible to solve the routing role, was chosen and described in details. The whole procedure of the method is described in details in the article [1], [5], [12-14].

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