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PROPOSAL FOR OPTIMIZING SPECIFIC DISTRIBUTION ROUTES BY MEANS OF THE SPECIFIC METHOD OF OPERATIONAL ANALYSIS

The paper focuses on the issue of optimizing material collection and distribution routes in the restrictive parameters. In the article, Clarke-Wright method was used, where the restricting parameters are vehicle capacity, vehicle speed and compliance with the social legislation related to the work of vehicle crew. The research aimed at the collection and distribution of steel components within a particular company. For the optimization, the data of weekly collection and distribution were used. By the Clarke-Wright method application, time savings of 40% of the vehicle use were achieved.

Keywords: *Clarke-Wright method, vehicle routing problem, route optimization*

1. Introduction

Currently, when transportation is one of the most developing sectors of industry and emphasis is put on its requirements, both from the customer´s and carrier´s side [1 - 2]. Transport logistics employs a number of technical, technological, organizational and management methods in order to ensure the transfer of goods [3], so that the delivery of goods is timely, in the right place, of the required quality and with required documentation [4]. Its aim is to maximize the effectiveness [5] at all levels of the transport process. Therefore it is necessary to optimize the overall effect by the control system [6].

In transport operation, each transport enterprise strives for reasonable financial impact [7]. For that reason, it is convenient to optimize the distribution routes [8] at their beginning and when changing the distribution plan. To achieve this, several methods can be employed. For the research needs, the Clarke-Wright method was chosen.

2. Solving vehicle routing problems

Currently, the transport problems being solved most concern the issue of vehicle routing problem. The tasks of vehicle routing problems are defined in the transport network S = (V, H), where V is a set of network nodes, while H designates the set of edges connecting the individual nodes of the network. V0 node is referred to as a centre point, whereas V1,.....Vn nodes represent the locations with a service demand. The vehicle route always starts and finishes at V0 centre. The task being solved within the solution of the vehicle routing problem is to design vehicle routes so that the demand for location service is satisfied by one vehicle with minimal costs in terms of length and/ or time [9].

Two basic constraints for the admissibility of the solution result from the definition of the task [9 - 11]:

1) Each customer must be served just once within a route,
2) The capacity of the vehicles must not be exceeded.

- In addition to the above mentioned preconditions, other conditions of the solution admissibility can be imposed on the set of vehicle routes being served, which modifies the original VRP, such as:

1) general conditions:

- o The number of elements possible to be transported within one route,
- o Constraints of a maximum drive time possible, or the length of one route (vehicle staff working hours which cannot be exceeded, compulsory resting times, prohibition of drives on certain days etc.),
- o Constraints resulting from the maximum number of serviced locations within one route in terms of the demands and vehicle capacity,

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- o Limited vehicle fleet; in the case of heterogeneous vehicle fleet, differences might be in technological capabilities and capacity of vehicles,

2) local conditions:

- o To respect time availability of the locations, i.e. to satisfy the demand of the location within a time window,
- o To respect technical availability of the locations, i.e. the customers demand for service by means of a vehicle of specific parameters,
- o Fuel consumption constraints; reasonable service costs etc. In the following part, the authors deal with the routing problem for the simple case, where a homogenous vehicle fleet is assumed, and where the vehicle route involves just one-circuit journey. If the drive time is limited, the route can consist of more circuit routes.

3. Methodology and method

For the research, Clark-Wright method was chosen, as it addresses the most typical multi-circuit routing problem with capacity constraints [9]. There is only one central point (a hub) from which the distribution and collection is carried out. From this point the distribution routes are conducted to other nodes. Each of the nodes has a different capacity. The total number of nodes must not exceed the vehicle capacity. There shall be a minimum total driving length.

This method is one of the older ones [12 - 13], with a focus on the solution of the vehicle routing problem. The method consists in choosing two routes (V0-Vi-V0) and (V0-Vj-V0). These routes are subsequently combined into one (V0-Vi-Vj-V0). Combining routes is possible provided that the vehicle capacity is not exceeded. The advantageousness or disadvantageousness of combining routes depends on the savings resulting from the combination. The savings are evaluated using zij coefficient of advantage, which is calculated as zij = (d0i + d0j – dij), where d0i, d0ja dij are distances assigned to edges (V0, Vi), (V0, Vj) and (Vi, Vj). The zij value is thus expressed as a difference between the sum of the route lengths (V0-Vi-V0) and (V0-Vj-V0) and the length of the combined route (V0-Vi-Vj-V0). The method combines the nodes with the higher zij coefficient of advantage in all iterations. The main advantage of this method is that the zij coefficient depends only on the distance between the nodes Vi, Vj and V0 and remains constant if these two nodes can be connected [13 - 14].

The above aforementioned method is employed in the following steps [9, 10 and 15]:

1) For the given transport network S = (V, H), matrix of distance D = {d(i, j)} is created, where i, j = 0,1,...,n; n = |V|. Usually, the S network does not have to be complete (i.e. in the graphical representation, it can be expressed by a graph which is not a complete graph), which means that the entries of D matrix can express both the length of the sectors and the distances between the individual nodes. In addition the following values should be entered:

where: c is the average speed of the vehicle within the network; t is time necessary for unloading the unit quantity of the elements from the service vehicle; T is maximum time the vehicle is allowed to stay outside the starting V0 node; K is the vehicle capacity; q_i is quantity of elements being transported from V0 node to node Vi (i = 1,...,n)

2) It is necessary to set initial solution which represents a set of elementary (V0 – Vi – V0) for all network nodes i = 1,...,n with a given number of elements and transport times (it may be complemented also by the times necessary for unloading the elements from the vehicle)
3) From D matrix, we derive Z matrix of the coefficient of advantage Z = {zij}, where i,j = 1,...,n resulting from zij = d0i + d0j – dij, where zij, as established, expressed the difference between the sum of the route lengths (V0 – Vi – V0) a (V0 – Vj – V0) and the length of the combined route (V0 – Vi – Vj – V0).
4) In Z matrix, positive element with the highest value zij is identified and if possible, the routes (V0 – Vi – V0) and (V0 – Vj – V0) are combined into one combined route (V0 – Vi – Vj – V0). If there is no such element, it is the final step. The current set of circuit routes is the result of the algorithm. Otherwise, this step should be followed by step 5).
5) By combining (V0 – Vi – V0) and (V0 – Vj – V0) routes admissible route should arise. If the route is not admissible, then zij should be zij = 0 and we should go back to step 4). Otherwise, this step should be followed by step 6).
6) V set of nodes is updated by excluding i and j nodes if they stopped being the outer nodes after combination of routes into one combined route. We establish zij = 0. The set of routes is updated by excluding combined routes and integrating a new route. At the same time, other monitored parameters (transport time, number of elements, route length etc.) is also updated. If step 4) and 5) is not possible, we must find the closest smaller or the same element and combine the routes.

The procedure is repeated until the Z matrix is exhausted or unless it is obvious that the vehicle capacity is exhausted and there is no point in looking for other solutions. The resulting solution is not always optimum, it is often just the suboptimal solution.

4. Determining the criteria for the application of clarke-wright method

In cooperation with a production company, for the application of Clarke-Wright method the route for distribution of steel components was chosen. The company has three vehicles for the distribution of the goods to its customers and for collection of the prepared material and its transport back to the production point. For the needs of this research, a weekly collection was chosen handled by IVECO Stralis EEV 460. The roster of individual routes is seen in Table 1. The Table was compiled based on the records of the operation of the vehicles in the week of October 14, 2016 to October 18, 2016. As the company specializes in different business activities, it operates the transport services only for its own vehicles. The transport services are a part of service provided to the customers and does not optimize the distribution routes. Each vehicle serves 5 routes. For the service of the remaining routes the company hires contract freighters [16 - 17].

Existing routes Table 1

Day	Route	Route length [km]	Mass [t]
Mo	C. B. - Horazdovice - C. B.	156	12
Tue	C. B. – Vinor - C.B.	354	11
Wed	C. B. – Kaplice - C.B.	64	9
Thu	C. B. – Hustopece - C.B	485	24
Fri	C. B. - Destna - C.B.	117	6
		1,176	62

Source: authors

Before the application of Clarke-Wright method, the route length is 1176 km and the mass of the transported material is 62t.

5. Forming of distance matrix and coefficient of advantage matrix

The basic step in the application of the aforementioned method is to form D (distance) matrix (see Table 2). The table was compiled according to Google maps.

Subsequently, from D matrix the matrix of coefficient of advantage will be derived (Z matrix). This matrix is formed based on the relation $Zij = d0i+d0j-dij$. The resulting Z matrix is seen in Table 3 [16 and 18].

Z matrix (coefficients of advantage matrix) Table 3

i/j	1	2	3	4	5
1	0	88	4	30	-1
2		0	2	154	78
3			0	2	1
4				0	110
5					0

Source: authors

6. Setting the initial elementary solution

Based on D (distance) matrix, initial solutions are set with regard to restricting. The time fixed for loading and unloading is 30 min. The determined average speed is 70 km/hour and the maximum vehicle load is 24t. Drivers´ working hours are set in accordance with the Labor Code in force [16, 18 and 19] - Table 4.

7. Discussion and resolutions

At this moment, the individual iterations according to the procedure step will be carried out [16, 17, 20 - 22].

1. Iteration 1 with max. zij. In Z matrix, positive element with the highest value (zij) will be found and the individual routes will be combined into one. In this case, it is number 154 which serves vertices V2 and V4. Based on this relation, route V0-V2-V4-V0 arises, with a total length of 832 km. By carrying out this iteration, the vehicle capacity would be exceeded. Therefore another more suitable combination will be sought.

Distance matrix Table 2

	steel/t- qi		12t	11t	9t	24t	6t
Matrix D		0	1	2	3	4	5
	i/j	Ceske Budejovice	Horazdovice	Vinor	Kaplice	Hustopece	Destna
0	Ceske Budejovice	0	75	161	31	238	55
1	Horadzovice		0	148	102	283	131
2	Vinor			0	190	245	138
3	Kaplice				0	267	85
4	Hustopece					0	183
5	Destna						0

Source: authors

Initial elementary solution Table 4

Elementary routes	mass [t]	Route length [km]	Drive time [hours]	Rest periods [hours]	Loading and unloading[hours]	Total time [hours]
V0-V1-V0	12	150	2.14	0	0.5	2.64
V0-V2-V0	11	322	4.6	0.75	0.5	5.85
V0-V3-V0	9	62	0.85	0	0.5	1.35
V0-V4-V0	24	480	6.85	0.75	0.5	8.1
V0-V5-V0	6	116	1.65	0	0.5	2.15

Source: authors

2. Iteration 2. We go on searching for a suitable solution with max zij = 110. The resulting route of this iteration is V0-V4-V5-V0. By carrying out this iteration, a route with exceeded vehicle capacity arises again, therefore will continue with iteration 3.
3. Iteration 3 with max. zij = 88. The combined route is accessible, as seen in Table 5, from which V0-V1-V2-V0 route arises. The length of the route is 472 km, the total time is 8.49 hours.
4. Iteration 4 with max. zij = 78. This iteration combines V0-V1-V2-V0 route, with V5 vertex. The vehicle capacity would thus be exceeded, since the driver´s working hours would be exceeded.
5. Iteration 5 with max. zij =30, concerning V4 vertex. Independent V0-V4-V0 route arises, as seen in Table 6.
6. Iteration 6 with max. zij = 4. This iteration would combine V0-V1-V2-V0 with V3 vertex. This is not admissible in terms of the driver´s working hours.

Iteration 3 Table 5

Route	q1+q2	Route length	Drive time	Loading + unloading	Rest period	Total time
V0-V1-V2-V0	23	472	6.74	1	0.75	8.49

Source: authors

Iteration 5 Table 6

Route	Q4	Route length	Drive time	Loading + unloading	Rest period	Total time
V0-V4-V0	24	480	6.85	0.5	0.75	8.1

Source: authors

Iteration 7 Table 7

Route	Q3	Route length	Drive time	Loading + unloading	Rest period	Total time
V0-V3-V0	9	62	0.88	0.5	0	1.38

Source: authors

Iteration 8 Table 8

Route	Q3	Route length	Drive time	Loading + unloading	Rest period	Total time
V0-V3-V5-V0	15	178	2.54	1	0	3.54

Source: authors

Resulting routes Table 9

Route	Q	Route length	Drive time	Loading + unloading time	Rest period	Total time
V0-V1-V2-V0	23	472	6.74	1	0.75	8.49
V0-V3-V5-V0	15	178	2.54	1	0	3.54
V0-V4-V0	24	480	6.85	0.5	0.75	8.1
In total		1,130				20.13

Source: authors

7. Iteration 7 with max. zij =2. The resulting route is V0-V3-V0, with a total length of 62 km (see Table 7).
8. Iteration 8 with max. zij = 1. V0-V3-V0 route is combined with V5 vertex. The resulting route is V0-V3-V5-V0 - Table 8.
9. The outcomes of the individual steps are summarized in Table 9

By applying the Clarke-Wright method it was found out that a substantial reduction in mileage is possible. Initially, there were 5 routes with the total length of 1,172 km. The company vehicles served the customers Monday to Friday, every day in a week. The customers who are not served by the company vehicles are served by means of the contract freighter hired by the company. By applying the Clarke-Wright method the number of routes was reduced. There was a decrease in mileage which will be reflected in the overall costs of the production company. The total length of the routes was reduced by 42 km in the whole week [22 - 24].

8. Conclusion

Nowadays, every company strives for reducing costs at all levels [21]. Each company focuses on its main business activities. Its weaknesses are in the areas they do not give 100% attention [25]. As regards the company mentioned in the study, the greatest attention is paid to production related activities. The transport services are provided only to its customers. In this area, the costs are not too high; therefore the company has not dealt with the issue yet. In the agreement with the company, the Clarke-Wright method was applied on one distribution [16 and 25].

Resulting from the application of the method, it was found out that cost savings would be possible in terms of reducing the number of routes and decrease in mileage within the routes. Based on the results of this research, the analyzed company could use the free days for serving other customers [19 and 24].

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