PERIODIC REPLENISHMENT WITH ZONING: A DISTRIBUTION COMPANY CASE STUDY

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Abstract: *The problem being studied in this paper stems from the requirement to distribute items from the warehouse to the client. Primarily, it was necessary to divide the distribution region to a number of zones, which represents a division of certain territory according to a specific criterion. By zoning these regions, periodic delivery of goods for PTT objects is enabled on certain days of the week. PTT objects are representing points in the region with a specific request for delivery -considering that each zone serves a certain day. The deliveries are divided into three groups: direct deliveries by tractor units, direct deliveries by trucks and small deliveries for milk run delivery. Two approaches were used to solve the routing problem: a heuristic clearing algorithm and a VRP solver. In addition, two zoning approaches were used: two zones with a PTT object balance, and three zones with a pallet balance.*

Keywords*: distribution, zoning, periodic replenishment*

1. INTRODUCTION

Problems of forming routes for vehicles (routing problem) represent a typical operational problem. When routing a vehicle, there is a set of transport requests that have to be performed. It is necessary to know the company's fleet. The task of routing is to determine all the routes to a certain location that vehicles must serve, in order to fulfil transport requirements. It is necessary to know the capacity of vehicles, as well as to try to minimize transport costs and also to respect the time interval for delivery. Different algorithms and methods have been developed for this problem (Vigo, 2014). In this case study, two methods have been applied. The idea of solving an existing problem using these methods is to obtain a good quality solution in the best possible way, and therefore to save money. Prior to routing, it is possible to perform zoning of the distribution region and allocation of days of the week, in which delivery is performed, with the idea of consolidating supplies and using the same vehicle fleet in different days by zones (periodic vehicle routing).

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Section 2 describes the problem of this case study, section 3 refers to the problem solving through two approaches, while section 4 presents the final results. Final considerations are given in Section 5.

2. PROBLEM DESCRIPTION – CASE STUDY

Data obtained from 3PL companies include data for March 2018 for nine regional centres located in Serbia. The total number of requests for delivery is 60,400 for the mentioned month. For this case study, three regional centres were observed that had the highest number of requests for delivery. The idea is that the delivery requirements are observed according to the capacity and number of pallets for each regional centre. In the current state of the company, the distribution of goods can be done every day - to every PTT object, six days a week. The PTT object is composed of several smaller objects which are located at near proximity. A heterogeneous fleet of vehicles was used. The conditions given in the observed case study are as follows: for small deliveries, one type of truck with a load of up to 4000 kg and 10 pallets is used, and these deliveries are routed. Direct deliveries are divided into large direct lines served by large capacity vehicles that can transport up to 23000 kg and 33 pallets, while small direct deliveries are realized by medium capacity vehicles that can transport up to 10000 kg and 20 pallets. Delivery data received from the company contains the required delivery dates, coordinates and quantities.

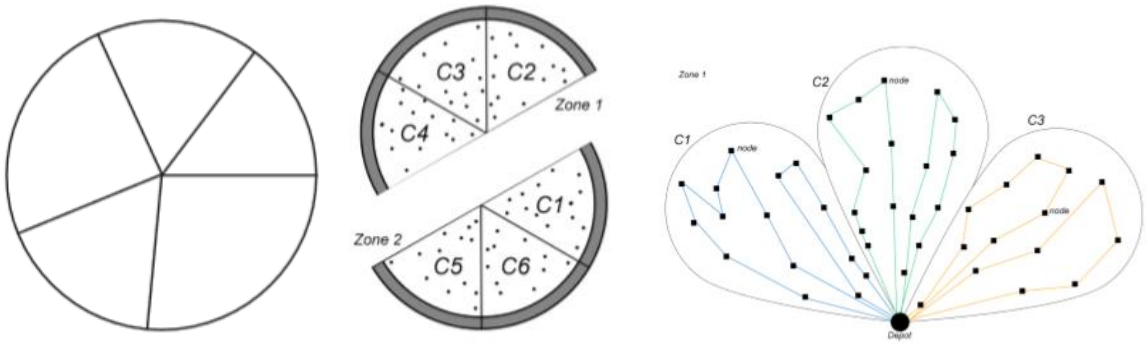

Figure 1. An example of distribution area zoning, Santana (2016)

3. SOLVING APPROACH

Solving approach is divided into four stages, which include: zoning, shifting of deliveries (between days), distribution of customer demands, and routing. Two approaches have been applied in solving routing problem, the first approach involves dividing into three zones (according to the number of pallets), while the second divides into two zones (according to number of PTTs). Moving deliveries between days according to zones is conducted in both approaches. The division of PTT deliveries for both approaches is the same: small shipments that are routed, large direct deliveries and small direct deliveries. Heuristic sweep algorithm was used for routing in the first, while in the second approach the excel tool VRP solver was used.

3.1. Two zone sweep algorithm approach

In this approach, the distribution centres were divided into two zones, where zone 1 is served on Monday, Wednesday and Friday, while zone 2 is operated on Tuesdays, Thursdays and Saturdays. Also, deliveries for PTT objects are consolidated according to assigned dates, where deliveries are always transferred to that specific zone for the day before.

For the routing of small deliveries, a heuristic sweep algorithm based on the application of polar coordinates was used, where the base is treated as a coordinate start (Santana, 2016). The coordinates used in the approach are given by the company as well as the real matrix of distances on the Serbian road network. The depot connects to the arbitrarily selected point and this point is called the first point. All other points connect to the base and then sort through the rising angles.

In this case, the TSP route is viewed as an approximation of the movement of the vehicle. The route begins with the first point, and then the remaining points join the route along the rising corners, taking care to respect the specified limits.

The second group of deliveries, or direct deliveries, are divided into those that are transported by large or medium capacity vehicles, all depending on the requested quantities. In case that the total delivery quantity, for a single PTT object, exceeds the number of pallets or the load capacity of the truck, more direct deliveries are formed.

3.2 Three zone VRP solver approach

The division of the zone was carried out according to the number of pallets, in three zones. Zone are balanced according to this parameter since it was assumed that the company uses its own fleet. After the division into zones, the shift of the delivery date was done in the following manner: all deliveries belonging to the zone 1 will be served on Monday and Thursday, those that belong to the zone 2 on Tuesdays and Fridays, and the deliveries that are in the zone 3 will be served on Wednesdays and Saturdays. Distribution of delivery depends on the initial conditions that are given.

VRP solver is used for routing, which provides solutions on the principle of the Large Neighborhood Search (LNS algorithm) used to solve the static problem. The necessary data entered in this tool are: number of depots, which is always one for each regional center; the number of objects to be serviced in one day, the average speed of the truck, the number of vehicle types (In this case one type of vehicle), whether it is necessary to return the vehicle to the depot. Other data that has to be filled are: locations, where is necessary to enter the names of the PTT objects, the coordinates, the service time of the facility, and the number of pallets that has to be delivered to each object. In the next sheet, the tool casts out all possible combinations of locations and it is necessary to enter the distances between each two PTT objects (data are given in the matrix of distance obtained from the company) and the time based on kilometres and the speed is calculated. In order to get the final solution, it is still necessary to enter the capacity data, the cash unit per kilometre, and the maximum number of vehicles a company can use for that day. The tool provides the ultimate solution where it shows total costs, how many vehicles have to be used, and the total kilometres travelled for each vehicle. On the basis of these data, the tool gives us a visual display of the route. For a more detailed view of how this tool works, as well as an overview of each step, take a look at Erdogan (2017).

4. COMPUTATIONAL RESULTS

Below are the results of zoning of one of the regional centres. Based on zoning, the service days were transferred, depending on the belonging to the zone. Figure 2 shows us a graphic representation of PTT objects for one regional centre. It is divided into two zones that are arranged according to polar coordinates. The first zone consists of the first 80 PTT objects, sorted by rising angles to half the number of objects, while the second zone has rest 79 PTT objects.

Figure 3 gives us a graphical representation of the space divided into three zones according to the number of pallets. On the basis of it, a clear difference is seen in the number of objects per zone, so zone 2 has the highest number of PTT objects, then zone 1 and at the end, zone 3 has the smallest number of PTT objects. The total number of pallets differs from the first approach, because all direct deliveries are excluded from observation before the zoning itself.

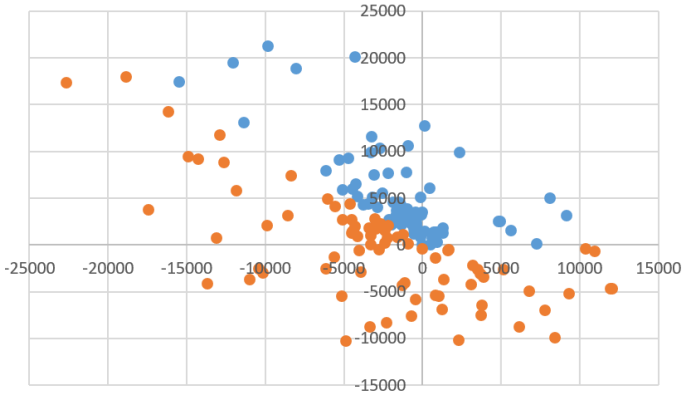

Figure 2. Graphic representation of PTT objects

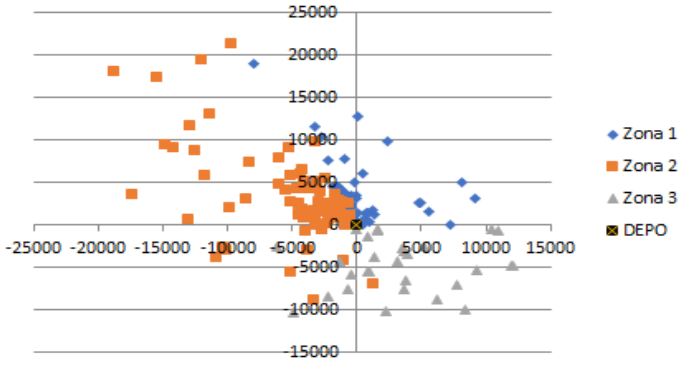

Figure 3. Graphical representation of three zones

Tables 1 is providing us with the ratio of the mass, the number of delivery pallets, and the number of PTT objects for one regional centre for two zoning approaches. By applying these two approaches we can see the balance by one criterion (in the first approach it is the number of PTT objects, while in the second it is the number of pallets) but also a disbalance according to other observed criteria.

Table 1. Overview of three basic parameters for zoning of one distribution region

	SWEEP ALGORITHM APPROACH		VRP SOLVER APPROACH		
	Zone 1	Zone 2	Zone 1	Zone 2	Zone 3
Kg	4161803.9	1615249.8	1208978.9	772552.7	1365426.5
Pallets	16665.9	4520.6	3258.0	3269.5	3258.6
Number of PTTs	80	79	45	74	29

Figure 4 shows us two visual views of one route (for two random days of the planning period). To the left is a large TSP route used to serve PTT objects classified in small deliveries on one day in March 2018. The route was obtained by a heuristic algorithm. On the right are several smaller routes, which are obtained using the VRP solver. Based on the entered data, the solver searches for a potential route solution to all locations, depending on the time and kilometre limit.

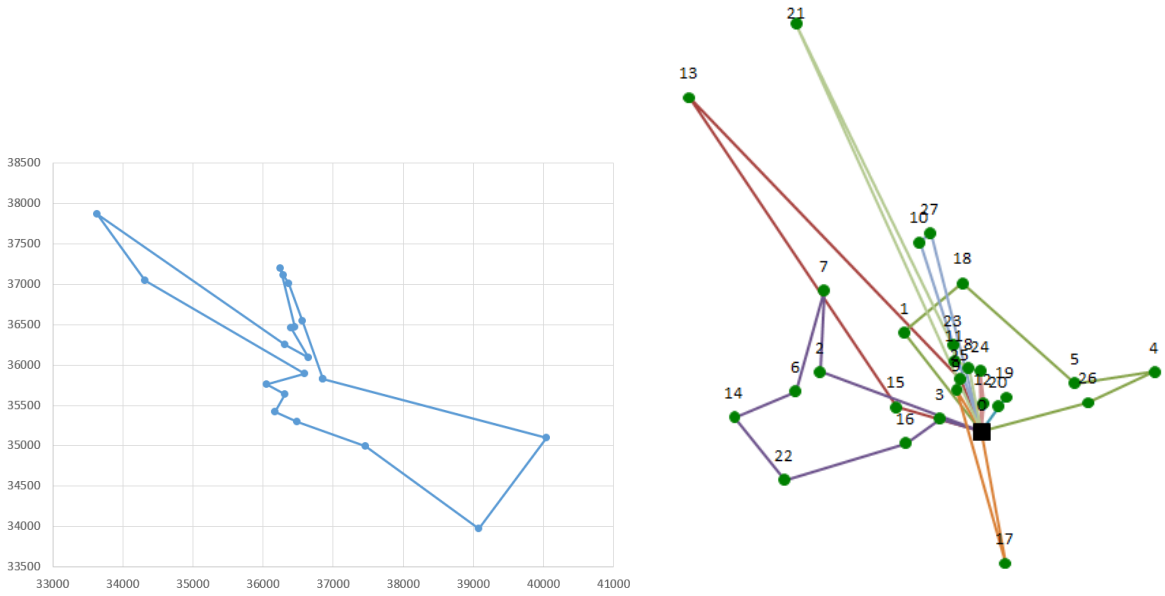

Figure 4. Example of vehicle routes obtained by two approaches

In Table 2, which presents the results of the first approach, can be seen that the cost reduction (given in monetary units) has decreased by 10% for all three observed regional centres. Significant savings occurred when small deliveries were realized, while large direct deliveries resulted in increased costs, which was expected.

Table 2. Results from the two zone sweep algorithm approach

		BEFORE ZONING				AFTER ZONING			
		100	104	105	Total	100	104	105	Total
LARGE DIRECT DELIV.	Km	17964.0	2683.7	18909.0	39556.7	19476.2	2683.7	18909.0	41068.9
	Cost	6826.3	1019.8	7185.4	15031.5	7401.0	1019.8	7185.4	15606.2
	Savings after zoning- direct deliveries by tractor units					*-8%*	*0%*	*0%*	*-4%*
MEDIUM DIRECT DELIV.	Km	22979.3	1630.5	14127.0	38736.8	23417.6	2075.2	16281.3	41774.1
	Cost	6572.1	466.3	4040.3	11078.7	6697.4	593.5	4656.5	11947.4
	Savings after zoning- direct deliveries by trucks					*-2%*	*-27%*	*-15%*	*-1%*
SMALL TRUCKS	Km	44970.0	28550.5	55057.8	128578.3	33182.8	21594.0	41804.7	96581.4
	Cost	10163.2	6452.4	12443.1	29058.7	7499.3	4880.2	9447.9	21827.4
	Savings after zoning- routing					*26.2%*	*24.4%*	*24.1%*	*24.9%*
TOTAL SAVINGS AFTER ZONING						**8%**	**18%**	**10%**	**10%**

Table 3 gives us individual and total costs, total kilometres, as well as savings for three regional centres using the second approach. Travel kilometres for routing has been reduced but they are increased for direct deliveries, while the overall savings for these three regional centres are significant and they are roughly equal to 25%.

Table 3. Results from the three zone VRP solver approach

		BEFORE ZONING				AFTER ZONING			
		100	104	105	Total	100	104	105	Total
LARGE DIRECT DELIV.	Km	9518.8	288.9	18908.9	28716.6	11632.7	477.6	20048	32158.3
	Cost	3617.1	109.7	7185.4	10912.2	4420.4	181.5	7618.516	12220.4
	Savings after zoning- direct deliveries by tractor units					*-18%*	*-24%*	*-6%*	*-12%*
MEDIUM DIRECT DELIV.	Km	39454.9	780.1	14126.9	54361.9	48096.6	971.2	14355.6	63423.4
	Cost	10284.1	223.1	4040.3	14547.5	13755.6	277.7	4105.7	18139.3
	Savings after zoning- direct deliveries by trucks					*-18%*	*-20%*	*-2%*	*-25%*
SMALL TRUCKS	Km	43458.4	16473.7	37285.1	97217.2	27354.9	11614.4	23236.6	62205.9
	Cost	9821.6	3717.1	8479.0	22017.7	6182.2	2624.8	5251.4	14058.4
	Savings after zoning- routing					*59%*	*42%*	*61%*	*26%*
TOTAL SAVINGS AFTER ZONING						**3%**	**24%**	**14%**	**24.9%**

5. CONCLUSION

By applying one of the approaches presented, the company could receive additional revenue in relation to the traditional approach they apply. Costs for direct deliveries have increased, due to the consolidation of deliveries in periodic replenishment strategy. The end result is a positive saving. From the attached results it can be noted that both approaches can generate significant savings, but they must be taken with reserve because a more detailed analysis, on a larger sample, is required, with a more complex structure of the vehicle fleet. As it is mentioned in Chapter 4, by applying these two approaches, there has been a balance of one of the three observed criteria, but also disbalance on other**s.** Also, it is necessary to consider the current behaviour of 3PL provider's clients who have the freedom to schedule delivery every day for all PTT objects, i.e it is necessary to attract clients to a new business model with periodic delivery to objects, where potential savings would be fairly distributed to both clients and 3PL provider.

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