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Enhancing variable neighborhood search by adding memory: Application to a real logistic problem

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ABSTRACT

This paper addresses a real problem of designing the routes over a planning period with flexibility in the dates of delivery. Specifically, a method based on the strategy Variable Neighborhood Search (VNS) is designed for this problem. The VNS-based method takes some ideas from *routing-first cluster-second* strategies for routing problems. In addition, it has two important features: it uses a memory-based shaking procedure and it allows, under some conditions, to move from the current solution to a worse solution (Skewed VNS). This procedure performs better than its basic version (no memory, not skewed). Computational experiments with real-data-based instances show that our VNS obtains better results than previous methods for this problem. The method is simple, with an easy implementation and can be adapted to other routing problems.

1. Introduction

The vehicle routing problem (VRP) is undoubtedly one of the most studied combinatorial optimization problems in literature. It can be defined as the problem of designing routes for delivering vehicles of given capacities, to supply a set of customers with known locations and requests from a single depot. Routes for the vehicles are designed to minimize some objective such as the total distance traveled.

In general, each client must be visited once; routes must begin and end at a central depot and capacity restrictions of the vehicle must be respected. Besides the basic VRP, many variants may appear since there are many possibilities in real-life problem settings, for example: pickup and delivery, backhauling, multiple depots, a heterogeneous fleet, multiple routes per vehicle, etc. There are many studies devoted to the exact and approximate solution for the different variants of this problem. As to general surveys of VRP, we refer to Toth and Vigo [69] and Cordeau et al. [15].

The VRP is NP-hard and therefore most of the literature has focused on heuristic solution methods, although some work on exact procedures has been published [23,33,68,42,26,15,5,6]. The literature on heuristic techniques is much more extensive: from the classical algorithm of savings of Clarke and Wright [12], the swap algorithm of Gillet and Miller [31], or the interesting algorithm of Fisher and Jaikumar [24] until the development of more modern metaheuristics. Vehicle routing problems exhibit an impressive record of successful metaheuristic implementations. Some of these are the following: genetic algorithms [57,67,58,43]; simulated annealing [51], Tabu Search [30,62,65,14,61]; greedy randomized adaptive search procedure, GRASP [39]; guided local search [71]; ant colony optimization [28], or Variable Neighborhood Search (VNS) as will be shown later in detail.

Other recent and interesting contributions for several VRP variants and logistic problems can be found in Dullaert et al. [22], Haghani and Jung [34], Mester and Bräysy [45], Kun et al. [40], Oppen and Løkketangen [49], Ropke and Pisinger [63], Xu and Chen [72], Doerner et al. [18], Mester and Bräysy [46], Pisinger and Ropke [53], Li et al. [41], Tarantilis and Kiranoudis [66], Bolduc et al. [8], Goel and Gruhn [32], Jozefowiez et al. (2008), Flisberg et al. [25], Prins [59], Zachariadis et al. [73], Duhamel et al. [20], Gajpal and Abad [27], Potvin and Naud [56], Brandão [9] and Duhamel et al. [21], Dewilde et al. [16], and Zarandi et al. [74]. A recent review about personnel scheduling including some routing problems can be found in Van den Bergh et al. [70].

The problem addressed in this paper is motivated by a real problem in a bakery company in Northern Spain. It was recently introduced in Pacheco et al. [52]. The company has to meet required orders, known in advance, for a set of distribution centers

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Table 1
Results of both VNS variants.

Instance N	#	Mean *f* SVNSM	Std *f* SVNSM	Mean *f* BVNS	Std *f* BVNS	Min *f*	B.R. by SVNSM	B.R. by BVNS	Mean time	Std time
41	1	**6425**	0.0	**6425**	0.0	6425	10	10	*9*	*0.7*
41	2	**6173**	0.0	**6173**	0.0	6173	10	10	*8*	*0.3*
41	3	**6356**	0.0	**6356**	0.0	6356	10	10	*8*	*0.1*
41	4	**6903**	0.0	**6903**	0.0	6903	10	10	*7*	*0.6*
41	5	**6833**	0.0	**6833**	0.0	6833	10	10	*6*	*0.1*
62	1	**9297**	0.5	9309	19.6	9297	5	1	*52*	*8.4*
62	2	**8765**	0.0	8809	44.7	8765	10	1	*58*	*11.3*
62	3	**8819**	16.3	8844	36.1	8814	9	4	*50*	*13.4*
62	4	**9089**	0.0	**9089**	0.0	9089	10	10	*33*	*0.2*
62	5	**8839**	4.3	8915	44.5	8838	9	0	*76*	*5.8*
82	1	**10734**	46.8	10780	72.7	10698	5	3	*215*	*100.7*
82	2	**10394**	4.3	10409	18.7	10389	4	4	*193*	*54.3*
82	3	**10080**	10.8	10101	28.2	10076	8	4	*188*	*47.6*
82	4	**10550**	0.0	**10550**	0.0	10550	10	10	*135*	*18.5*
82	5	**10560**	2.1	10604	58.3	10556	2	0	*161*	*22.7*
102	1	**13081**	11.0	13124	49.8	13077	9	9	*360*	*107.8*
102	2	**13799**	0.6	13801	2.8	13799	8	4	*325*	*89.5*
102	3	**11879**	10.6	11914	26.5	11870	3	0	*448*	*109.2*
102	4	**12304**	0.0	12324	43.4	12304	10	8	*315*	*44.6*
102	5	**12476**	7.9	12490	23.0	12468	4	2	*544*	*163.0*

over a week using a fleet of homogeneous vehicles. Each order includes a number of required pallets and a specific delivery day (*deadline*). Each trip finishes on the same day when it started, and the vehicles return to the depot at the end of the route.

The total travel costs over the week might be reduced by combining orders, since it is possible to take advantage of certain flexibility in the delivery date. Nevertheless, as the company is dealing with perishable products, every order should not be delivered more than one day ahead of the original deadline. This policy will result in stock at the distributors, but this is controlled and acceptable for the company. Although, initially this problem has been proposed by a bakery company, it is clear that the same problem or similar ones can be found in other areas.

This paper proposes a method based on the metaheuristic VNS for this problem. VNS is a local search based metaheuristic which was first proposed by Mladenović [47], Mladenović and Hansen [48] and Hansen and Mladenović [36]. The VNS approach has already been successfully applied to different variants of the VRP's (see e.g. [10,55,54,38,37,60].

Specifically, our VNS-based method takes some ideas from *routing-first cluster-second* strategies for routing problems. Additionally, it has two other characteristics: first, the use of memory in the *shaking* process, and second the possibility of moving from the current solution to a worse solution (Skewed VNS). Both characteristics show to be effective and efficient and improve the basic version of the method (Basic VNS). This basic version uses a completely random *shaking* process (without memory) and only improvement moves are allowed (non-Skewed). Also, as will be shown, our proposed method obtains better results than other procedures previously proposed and properly adapted for this problem. Moreover, it is very simple, can easily be implemented, and some ideas can be adapted to similar routing problems. The latter is explained at the end of Section 4.

The variant Skewed VNS was introduced by Hansen et al. [35]. Recent applications can be found in de Souza and Martins [64], Brimberg et al. [11], Dong et al. [19], and Maximiliano et al. [44]. On the other hand, the use of memory in VNS methods can be found in Garcia et al. [29] in the context of linear ordering problems. However, to the best of our knowledge, no methods based on VNS with memory designed ad hoc for routing problems have been known so far.

The main contribution of this paper is the design of a simple VNS method for routes sustained by the incorporation of memory. Adding memory, as will be shown next, increases the algorithm's efficiency. The method is simple, easy to implement, and can be adapted relatively easy to similar problems of logistics and routing.

The paper is organized as follows. The following section presents the notation and the description of the problem. In Section 3 we describe the basic VNS method for this problem. In Section 4 we discuss the method of Skewed VNS with memory, which has been designed by properly modifying the basic VNS. Section 5 is devoted to the parameter fine tuning. In Section 6 we present the results of different computational experiments. Finally, Section 7 concludes with our main findings.

2. Problem description and notation

In this paper we address a problem that arises in a bakery company, which has to deliver orders placed by geographically dispersed distribution centers in northern Spain. Orders for the week are known in advance, commonly on Friday of the previous week. The problem has the following characteristics.

Regarding orders:

- Each order includes a number of required pallets which need to be delivered on a specific day(*deadline*).
- Each order must be delivered by a single vehicle (due to labor constraints at distribution centers).
- Each order should be delivered by the original deadline and no more than a fixed number of days before the deadline, but always within the same week. This means that if the deadline of an order is Monday, it cannot be delivered before that day.

Regarding routes:

- To meet the orders a fleet of homogeneous vehicles with known capacity is available.
- Each trip finishes on the same day it started and the vehicles return to the depot at the end of the route.
- Transportation costs are in proportion to the distance traveled.

The problem consists of designing routes to deliver the orders placed for the week with the objective of minimizing the total transportation cost, that is, the total traveled distance. Flexibility of the delivery day plays an important role in the solution of the problem. By managing this flexibility, it is intended to create sav-