Heuristics for the Periodic Mobile Piston Pump Unit Routing Problem

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ABSTRACT

The Periodic Mobile Piston Pump Unit Routing Problem consists of, given a set of surface oil wells scattered over an onshore producing field, determining routes for each day of work, with limited duration work shift, that maximize the collection of oil carried by a mobile piston pump unit. This paper presents different construction and local search methods used in the composition of GRASP and ILS heuristics for the problem. Experimental results demonstrate the effectiveness of the proposed method.

Keywords: Combinatorial Optimization, GRASP, ILS, Metaheuristics, Oil Pumping, Vehicle Routing Problem

INTRODUCTION

This paper presents a practical application of the Vehicle Routing Problem (VRP), where, one or more vehicles from a homogeneous fleet leave a storage facility, visit a set of customers, and, at the end of the activities, return to the initial facility. The customers should be visited by just a single vehicle and the aim is to minimize the cost of the route for each vehicle meeting the demand of customers. The problem addressed in this paper is a practical application of the regular version of the VRP, which consists in solving the problem of finding optimized routes for one or more mobile piston pump units (MP-PUs) in onshore fields containing non-artesian wells, within a previously established period. This problem is called Periodic Mobile Piston Pump Unit Routing Problem (PMPPURP) and has been addressed by some works in the literature. (Aloise, Santos, Barros, Souza & Noronha, 2001; Goldbarg, E. F. G, Goldbarg, M. C., & Neto, 2004; Goldbarg, E. F. G, Goldbarg, M. C., & Duarte, 2010).

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Among the available metaheuristics in literature, GRASP (Feo & Resende, 1989; Resende & Ribeiro, 2003) proved to be one of the most efficient methods to solve various combinatorial optimization problems (Aloise et al., 2000; Layeb, Ammi & Chikhi, 2013; Neves and Ochi, 2006). The Iterated Local Search (ILS) metaheuristic (Lourenço, Martin & Stützle, 2003; Lourenço, Martin & Stützle, 2010) also has been successfully used and good quality results have been obtained when adopting it as a global optimization technique applied to the solutions generated by GRASP (Junior, Arroyo & Souza, 2010; Prins, 2009; Zeferino, Amorim & Filho, 2011).

In this context, we propose a new heuristic algorithm using GRASP and ILS concepts to solve the PMPPURP, whose goal is to collect the largest possible amount of oil during a given period of activities. We present different versions of constructive algorithms and local search methods used to implement a GRASP and ILS framework.

The article is organized as follows: The second section gives an overview of the PMPPURP. The third section reviews some relevant literature. The fourth section introduces a mathematical model formulation for the problem. The fifth section presents the proposed GRASP heuristic. The sixth section presents the computational results and in the seventh section conclusions and future avenues of research are discussed.

**THE PERIODIC MOBILE PISTON PUMP UNIT ROUTING PROBLEM**

The vehicle routing problem can be applied in a scenario observed in the northeastern region of Brazil, between the states of Rio Grande do Norte and Ceará, called Potiguar basin. This is an area well known for their petroleum exploration land fields, classified as artesian, which means the internal pressure of the gases is sufficient to lift the oil to the surface, and non-artesian, for which it is necessary to use mechanical equipment to collect the oil.

The determinant factor to decide the operation method to be used for non-artesian wells is their productivity. If the well has a high production, a stationary pumping equipment is installed in the location of each well. A pumping system using mobile piston pumping units (MPPU) can be adopted to extract oil from lower productivity wells, that present a relevant production level, but which the installation of a stationary equipment is not financially interesting.

A MPPU consists of a truck with a storage tank and all the necessary machinery for the pumping operation, which can be set in a short amount of time. After completing the pumping operation on a well, the unit is free to move toward another well and repeat the operation, while the well that was just visited begins its natural refilling process until the column of fluid reaches its static level.

A region of non-artesian wells, as observed in Potiguar basin, may cover thousands of square miles and contains a significant number of wells classified as potential candidates for the pumping process. So, it is important to develop a method to establish, for each day of a planning period, sets of routes containing subsets of the wells in order to manage that the total distance traveled by the MPPUs and the volume of oil collected be as productive as possible.

Thus, the Periodic Mobile Piston Pump Unit Routing Problem (PMPPURP) consists, for each day of a planning period, to establish an optimized scheduling of visits to non-artesian wells so that the volume of collected oil is maximized, and each route starts and ends in a treatment plant oil (TPO), where the MPPU discharges the collected oil.

The route’s definition must take into account the worker’s shift duration, and for practical purposes, an auxiliary tanker truck follows the MPPU to prevent it to return before the end of the workers shift due to the possibility of exceeding its storage capacity. For practical purposes, the storage capacity of the vehicle is considered unlimited (Aloise et al., 2001; Goldbarg et al., 2004).
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