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A flexible adaptive memory-based algorithm for real-life transportation operations: Two case studies from dairy and construction sector

C.D. Tarantilis [a,*], C.T. Kiranoudis [b]

[a] *Department of Management Science and Technology, Athens University of Economics and Business, 47A Evelpidon Street/33 Lefkados Street, Athens 113-62, Greece*
[b] *Department of Systems Analysis, Design and Development, National Technical University of Athens, Athens 157-80, Greece*

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Abstract

Effective routing of vehicles remains a focal goal of all modern enterprises, thriving for excellence in project management with minimal investment and operational costs. This paper proposes a metaheuristic methodology for solving a practical variant of the well-known Vehicle Routing Problem, called Heterogeneous Fixed Fleet VRP (HFFVRP). Using a two-phase construction heuristic, called GEneralized ROute Construction Algorithm (GEROCA), the proposed metaheuristic approach enhances its flexibility to easily adopt various operational constraints. Via this approach, two real-life distribution problems faced by a dairy and a construction company were tackled and formulated as HFFVRP. Computational results on the aforementioned case studies show that the proposed metaheuristic approach (a) consistently outperforms previous published metaheuristic approaches we have developed to solve the HFFVRP, and (b) substantially improves upon the current practice of the company. The key result that impressed both companies' management was the improvement over the bi-objective character of their problems: the minimization of the total distribution cost as well as the minimization of the number of the given heterogeneous number of vehicles used.

Keywords: Metaheuristics; Vehicle routing system; Industrial logistics; Construction project management

1. Introduction

Distribution and transportation of materials is an intense problem faced by major industrial and construction companies in many countries. In this paper we address the problem of the distribution

* Corresponding author. Tel.: +30 210 8203677; fax: +30 210 8816705.
E-mail address: tarantil@aueb.gr (C.D. Tarantilis).

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of materials to customers' locations (e.g., ranging from food stores to construction sites). The problem is of particular importance since the relevant costs (acquisition of delivery vehicles or concrete-mixer trucks and their operation, i.e., cost of labour) constitute a large proportion of the overall investment and operational costs of a producer or a constructor or a dispatcher in general [6].

In this paper we address two planning problems; the first concerning the distribution of perishable foods for a major dairy company and the second dealing with the distribution of ready concrete for a construction company.

The first case study considers a central warehouse of a dairy company that hosts a heterogeneous fleet of vehicles and stores perishable foods (e.g., bottles of fresh milk) that have to be delivered to a set of customers satisfied through daily deliveries. The distance between each pair of customers is known, as is between the central warehouse and each customer's location. After performing all deliveries, each vehicle route ends at the central warehouse [6].

The second actual case study we address in this paper can be accurately described as follows. Consider a distribution centre of a construction company where ready concrete is loaded on appropriate heterogeneous fleet of concrete-mixer trucks. Ready concrete has to be delivered to a set of construction sites. Every construction task can be served by a specific type of concrete-mixer truck of different capacity that can carry different blend of concrete (i.e., different qualities of ready concrete). Concrete-mixer trucks unload the demanded quantities at each construction site, and after visiting all demand points, they return to the distribution centre.

Both the dairy and the construction applications are cases of a variant of the well-known Vehicle Routing Problem (VRP) [1,8,10,20], called Heterogeneous VRP (HVRP). Although the heterogeneous fleet version of VRP is more realistic than the classic-homogeneous fleet VRP, it has attracted much less attention than the latter. The majority of the papers have dealt with a version called Vehicle Fleet Mix Problem (VFMP), in which the number of vehicles in each type is unlimited and each vehicle of type t has a fixed cost C_t and a cost per distance unit V_t. The VFMP aims at designing a set of minimum total cost (e.g., the sum of fixed and travel costs) vehicle routes. Osman and Salhi [12] considered vehicle-independent variable costs, while Gendreau et al. [7], Taillard [19] and Renaud and Boctor [16] vehicle dependent variable costs.

In realistic vehicle routing problems involving heterogeneous fleet (HVRP) addressed in this paper, the number of vehicles of each type is *fixed*. This version of the HVRP is known as Heterogeneous Fixed Fleet VRP (HFFVRP). The HFFVRP is much harder to be solved than the classical VRP and the VFMP: The most effective current metaheuristics employed for solving both the classical VRP and VFMP use local search techniques based on intra- or inter-route customer exchanges and variable pool-based procedures [7,17,19]. The feasibility check or the evaluation of these moves for the classic VRP is an easy task because vehicles involved are identical. On the contrary, the feasibility check or the evaluation of a move for the HFFVRP, requires finding a new assignment of the vehicles to the new solution's routes. It is clear that this re-assignment of vehicles to routes is difficult, due to the fixed number of heterogeneous vehicles. Contrary to HFFVRP, the re-assignment problem is not so difficult for the VFMP where the number of vehicles of each type is unlimited (since each route is performed by the cheapest vehicle type with respect to capacity constraints). To our knowledge, only the papers of Taillard [19] and Tarantilis et al. [22,23] have attacked the HFFVRP.

Apart from the aforementioned version of the HVRP, several different formulations with additional operational constraints have been presented recently: Prins [14] describes several heuristics to solve the HFFVRP and the optional possibility for each vehicle to perform several trips. Liu and Shen [11] and Dullaert et al. [5] describe heuristic methods for the HVRP with unlimited number of vehicles of each type and time windows constraints (HVRPTW), while Dondo et al. [4] developed a mathematical formulation of the multiple-depot HVRPTW, and highlighted the employment of some elimination rules to get a significant reduction on the problem size and tackle larger instances of the problem.