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Multi-Criteria Optimization for Fleet Size with Environmental Aspects

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Abstract

This research concerns multi-criteria vehicle routing problems. Mathematical models are formulated with mixed-integer programming. We consider maximization of capacity of truck vs. minimization of utilization of fuel, carbon emission and production of noise. The problems deal with green logistics for routes crossing the Western Pyrenees in Navarre, Basque Country and La Rioja, Spain.

We consider heterogeneous fleet of trucks. Different types of trucks have not only different capacities, but also require different amounts of fuel for operations. Consequently, the amount of carbon emission and noise vary as well. Companies planning delivery routes must consider the trade-off between the financial and environmental aspects of transportation. Efficiency of delivery routes is impacted by truck size and the possibility of dividing long delivery routes into smaller ones.

The results of computational experiments modeled after real data from a Spanish food distribution company are reported. Computational results based on formulated optimization models show some balance between fleet size, truck types, utilization of fuel, carbon emission and production of noise. As a result, the company could consider a mixture of trucks sizes and divided routes for smaller trucks. Analyses of obtained results could help logistics managers lead the initiative in environmental conservation by saving fuel and consequently minimizing pollution.

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Keywords: Multi-Criteria Decision Making; Vehicle Routing; Green Logistics; Heterogeneous fleet.

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1. Introduction

In this paper we consider the group of green vehicle routing problems, specifically the maximization of capacity of trucks vs. the minimization of utilization of fuel, carbon emission, and noise production. We consider heterogeneous fleet of trucks. Different types of trucks have not only different capacities, but also require different amounts of fuel for operations. Consequently, the amount of carbon emission and noise vary as well. Companies planning delivery routes must consider the trade-off between the financial and environmental aspects of transportation. Efficiency of delivery routes is impacted by truck size and the possibility of dividing long delivery routes into smaller ones.

Because road transportation is a leading way of transporting goods all around the world, truck emissions must be controlled. The environment is highly valued within the trucking industry; over the years the there have been several efforts to reduce fuel consumption and emissions. Many more steps can be taken, such as designing more efficient engines, optimization of vehicles and trains, and changing vehicle total weight. For example, Volvo aimed to reduce fuel consumption by approximately 38% from 1980 to 2009 (Volvo, 2014). Similarly, Mercedes-Benz has proved their evolution from 1996 till 2016, during which they have reduced heavy truck fuel consumption by 22%, a reduction of at least 50 million tons in the CO_2 in Europe (Daimler, 2016).

Additional factors to consider concerning truck emission reduction include payload, trailer cargo volume, and maximum speed limits. These factors differ notoriously in the European and US markets. Maximum speed limits are higher in the US than in Europe. Similarly, US trucks can legally transport 21% more volume than European trucks. However, EU trucks emit 16% less CO_2 overall than US trucks (ACEA/EAMA, 2016).

Computational results based on formulated optimization models show balance between fleet size, truck types, utilization of fuel, carbon emission, and noise production. As a result, the company could consider a mixture of trucks sizes and divided routes for smaller trucks.

For computational experiments, exact solution methods are applied for finding suboptimal solutions. The CPLEX solver, using the AMPL programming language, is used to solve such models (Fourer et al., 1990). This research has been performed using real data from the Spanish grocery company Eroski. This research problem deals with green logistics for routes crossing the Spanish regions of Navarre, Basque Country and La Rioja. The results of the current analysis may be helpful for logistics managers to lead the initiative of constructing routes, which have a lower environmental impact.

1.1. Road transportation

Road transportation is both important for economic development and harmful to the environment because of externalities such as pollution and noise (Koç et al., 2016; Kovacs et al., 2015, Grafton et al., 2004). For many years, the planning of freight transportation by road mainly focused on cost minimization. Increasing concern for the environment has recently led logistics managers and freight carriers to focus their attention on the formulations of transportation problems that include environmental aspects of transportation (Koç et al., 2016; Demir et al., 2014a; Sawik et al., 2017a, 2017b, 2017c, 2016a, 2016b, 2015).

1.2. Vehicle Routing Problem

The vehicle Routing Problem (VRP) has been studied since 1959 with the objective to minimize the total distance travelled by all vehicles. There are several variants to the VRP (Toth and Vigo, 2014). These are formulated based on the nature of the transported goods, the quality of service required, and the characteristics of the customers and vehicles. Other problem variations were derived from this basic problem, such as VRP with time windows (VRPTW), capacitated VRP (CVRP), multi-depot VRP (MDVRP), site-dependent VRP (SDVRP), the open routing problem (OVRP), Cumulative VRP (CumVRP), and finally the green vehicle routing problem (G-VRP) which considers environmental aspects of transportation (Koç et al., 2016; Demir et al., 2014a, Gaur et al., 2013; Lin et al., 2014, Erdogan et al., 2012; Sawik et al., 2017a, 2017b, 2017c). Other studies concern variations of the VRP, such as Oberscheider et al., (2013), in which the problem is formulated as a multi-depot vehicle routing problem with pick-up and delivery and time windows (MDVRPPDTW).