Chapter 2

Vehicle Routing Models and Algorithms for Winter Road Spreading Operations

Nathalie Perrier
École Polytechnique de Montréal, Canada

James F. Campbell
University of Missouri-St. Louis, USA

Michel Gendreau
École Polytechnique de Montréal, Canada

André Langevin
École Polytechnique de Montréal, Canada

ABSTRACT

Winter road maintenance operations involve challenging vehicle routing problems that can be addressed using operations research (OR) techniques. Three key problems involve routing trucks and specialized vehicles for spreading chemicals and abrasives on roadways, snow plowing, and snow disposal, all of which are undertaken in a very difficult and dynamic operating environment with stringent level of service constraints. This chapter provides a survey of recent optimization models and solution methodologies for the routing of vehicles for spreading operations. The authors also present a detailed classification scheme for spreader routing models developed over the past 40 years. Key trends in recent model developments include the inclusion of more details of the practical operating constraints, the use of more sophisticated hybrid solution strategies and consideration of more comprehensive models that integrate vehicle routing with models for other related strategic winter maintenance problems. They highlight some factors that may be limiting the application of OR models in practice and discuss promising future research trends.

DOI: 10.4018/978-1-61350-086-6.ch002
1. INTRODUCTION

There are many challenging and expensive winter road maintenance decision problems that can be addressed using operations research techniques. A key operation is spreading of chemicals and abrasives on the road network, which is conducted on a regular basis in almost all rural and urban regions that experience significant snowfall or roadway icing. The importance of winter road maintenance operations is obvious from the magnitude of the expenditures required to conduct winter road maintenance operations, as well as the indirect costs from both the lost productivity due to decreased mobility and from the effects of chemicals (especially salt) and abrasives on infrastructure, vehicles and the environment. In the US alone, 70% of the population and 74% of the roads are in snowy regions and state and local government agencies spend over US $2.3 billion (US) per year for snow and ice control activities (Federal Highway Administration [FHWA], 2010; Pisano, Goodwin, & Stern, 2002). Indirect costs (e.g., for environmental degradation, economic losses and mobility reductions) are thought to be several times larger; for example, the costs for weather-related freight delays in the US have been estimated at US $3.4 billion (US) per year (Nixon, 2009).

Recent developments in winter road maintenance technologies and operations improve efficiency, reduce resource (materials, equipment and personnel) usage, and minimize environmental impacts (Shi et al., 2006; Transportation Research Board [TRB], 2005, 2008; Venner Consulting and Parsons Brinkerhoff, 2004). These developments include use of alternative deicing materials, anti-icing methods, improved snow removal equipment, more accurate spreaders, better weather forecasting models and services, road weather information systems, vehicle-based environmental and pavement sensors, etc. These new technologies, and their growing use by state and local government agencies, have improved the effectiveness and efficiency of winter maintenance operations, benefiting government agencies, users, and the general public.

While new winter road maintenance technologies are being developed and deployed on a broad basis, implementations of optimization models for winter road maintenance vehicle routing remain very limited. Most agencies continue to design vehicle routes based on manual approaches derived from field experiences and most agencies rely on static weather forecasts (Fu, Trudel, & Kim, 2009; Perrier, Langevin, & Campbell, 2007a, 2007b). As Handa, Chapman, and Yao (2005) note, “In practice [route] optimization has traditionally been a manual task and is heavily reliant on local knowledge and experience” (p. 158). The limited deployment of optimization models for winter road maintenance vehicle routing is especially surprising given the documented successes in other areas of arc routing, perhaps most notably for waste management (Sahoo, Kim, Kim, Kraas, & Popov, 2005). Thus, winter road maintenance vehicle routing optimization would appear to offer the promise of significant cost savings, along with a reduction in negative environmental and societal impacts.

There are probably many reasons for the limited field use of vehicle routing optimization. In large part, this has been due to the complexity of the problems studied, which in turn is derived from the difficult operating environment. However, it also results from the unique organizational characteristics of the winter road maintenance agencies. Winter road maintenance decisions problem, including vehicle routing for spreading (and plowing), are more complex than most other arc routing problems because of unique characteristics of each site and agency, and the tremendous diversity in operating conditions such as geographical location, climatic and weather conditions, demographics, economics, technological innovations (for materials application, mechanical removal, and weather monitoring), legislative requirements, interagency agreements,
Related Content

Pseudorandom Number Generators Based on Cellular Automata
(2018). *Formation Methods, Models, and Hardware Implementation of Pseudorandom Number Generators: Emerging Research and Opportunities* (pp. 52-65).
[www.irma-international.org/chapter/pseudorandom-number-generators-based-on-cellular-automata/190213/](www.irma-international.org/chapter/pseudorandom-number-generators-based-on-cellular-automata/190213/)

Concept Science: Content and Structure of Labeled Patterns in Human Experience
[www.irma-international.org/chapter/concept-science/186511/](www.irma-international.org/chapter/concept-science/186511/)

Core-Based GRASP for Delay-Constrained Group Communications
[www.irma-international.org/article/core-based-grasp-for-delay-constrained-group-communications/101777/](www.irma-international.org/article/core-based-grasp-for-delay-constrained-group-communications/101777/)

Texture-Based Land Cover Classification Algorithm Using Hidden Markov Model for Multispectral Data
[www.irma-international.org/chapter/texture-based-land-cover-classification-algorithm-using-hidden-markov-model-for-multispectral-data/190177/](www.irma-international.org/chapter/texture-based-land-cover-classification-algorithm-using-hidden-markov-model-for-multispectral-data/190177/)

Three Scenarios in Microgrid to Solve Management Problem for Residential Application Using Genetic Algorithms