MODELS AND METAHEURISTICS FOR VEHICLE ROUTING PROBLEMS UNDER UNCERTAINTY

by

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Certificate of Authorship/Originality

I, Chenlian Hu declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Computer Science, Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree at any other academic institution except as fully acknowledged within the text. This thesis is the result of a Collaborative Doctoral Research Degree program with the Shanghai Jiao Tong University.

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Abstract

Within the logistics and transportation industry, the vehicle routing problem (VRP) bears significant importance in many real-life logistics activities. As one of the most important and widely studied combinatorial optimization problems in the past sixty years, the VRP, also known as the capacitated VRP (CVRP), focuses on minimizing transportation costs: it concerns how to serve a set of geographically dispersed customers with a fleet of homogeneous vehicles at minimum cost. Given the potentially substantial savings from optimizing routing strategies in practical logistics activities, various complex extensions of the CVRP inspired from real-life applications have increasingly received attention. In the CVRP and most of its extensions, a common assumption is that the values of all problem parameters are readily available and can be precisely known in advance. However, this assumption does not invariably hold in many practical routing problems due to uncertainty, which could be secondary to factors such as imprecise information on customer demands, unfixed service times for customers, and varying travel times for vehicles. Thus, routing strategies generated without considering uncertainty may ultimately be found infeasible in real-life applications.

This thesis aims to study several important extensions of the CVRP under uncertainty. To model these problems, we adopt the robust optimization paradigm which is an effective framework for optimization problems with uncertain data. Given their complexity, we focus on developing efficient metaheuristic solution approaches. Our investigations are threefold. Firstly, we study the vehicle routing problem with time windows considering uncertainty in customer demands, service times, and travel times. To capture these different types of uncertainty, novel route-dependent uncertainty sets are defined. The problem is modelled through a robust mathematical formulation with the route-dependent uncertainty sets and solved via a metaheuristic based on the adaptive variable neighbourhood search method. Secondly, we study the vehicle routing problem with simultaneous pickup and delivery and time windows under uncertainty in pickup demands and travel times. A robust mathematical formulation with two route-dependent uncertainty sets is presented to model the problem and a metaheuristic based on the adaptive large neighbourhood search method is proposed to solve it. Finally, we study the two-echelon multiple-trip vehicle routing problem with time windows and satellite synchronization under customer demand uncertainty. This problem considers a two-echelon transportation system and a number of practical features commonly observed in city logistics. A robust mathematical formulation with a novel demand uncertainty set and a metaheuristic based on the variable neighbourhood search framework are accordingly proposed. We conduct extensive numerical experiments which employ benchmark instances from the literature. The computational results show that the proposed solution approaches can generate high-quality deterministic and robust solutions for large-sized instances within a reasonable running time. In addition, Monte Carlo simulation tests are designed to evaluate the robustness of the obtained solutions. Useful managerial insights for decision-makers in the logistics and transportation industry are derived from a comprehensive analysis of the computational results.

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