Service Reliability in Urban Transportation

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Abstract

This work aims to establish reliable vehicle routing plans in an urban transportation environment, where uncertain travel times take place. More specifically, the goal is to present a mathematical model and a solution method for the combined Vehicle Routing (VRP) and Time Window Assignment Problem (TWAP) with stochastic travel times.

Nowadays, urban transportation has become a research field of great importance mainly because of the problems occurred when distributing goods, personnel and other services in large cities with high density population. In addition, the rapid growth of the internet sales and the e-commerce operations adopted by the retail companies has increased the direct-to-consumer deliveries. In a real-life urban environment the travel times are stochastic as the speed of vehicles varies due to the variability in traffic flows caused by the weather conditions, the traffic congestion in rush hours, different road types and speed limits, the road conditions, car accidents. The uncertain arrival times make a deterministic routing plan that is a priori scheduled unrealistic and unreliable, especially when just-in-time policies are adopted (Lecluyse et al., 2009). The uncertainty is very difficult to be predicted and the customers are usually served outside their time windows. For that reason, integrated transportation systems that incorporate high-tech information systems and real-time data analytics can be used to achieve more reliable service against the uncertainty created by the urban transportation (Savelsbergh and Woensel, 2016).

The focus of the current research is to design least cost routes of homogenous vehicles with limited capacity that serve a set of geographically dispersed customers (VRP) and at the same time to provide the customers with time windows achieving reliable service against the uncertainty in travel times (TWAP). The stochastic travel times are modeled via discrete random variables according to a set of scenarios that implies the duration to traverse each arc. The service reliability is attained by probabilistic chance constraints, which capture the probability mass of the stochastic arrival times that fall within the time window at each customer. A two stage hierarchical solution framework has been adopted for solving the combined problem. Initially, the master vehicle routing problem is solved via an Adaptive Large Neighborhood Search metaheuristic algorithm (Pisinger and Ropke, 2007). At the second stage, the subordinate time window assignment mixed integer sub-problems are solved for each route imposing the time windows to customers. Finally, a set of computational experiments is performed on well-known benchmark instances and the trade-off between routing cost and service reliability is examined.

Keywords
Vehicle routing, stochastic travel times, service reliability, time windows

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