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**Two-Echelon Prize-Collecting Vehicle Routing with Time Windows and Vehicle Synchronization: A Branch-and-Price Approach**

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The steady growth in e-commerce and grocery deliveries within cities puts a strain on the available infrastructure in urban areas by increasing the total number of freight movements, aggravating traffic congestion, as well as air and noise pollution. In this context, this research introduces the Two-Echelon Prize-Collecting Vehicle Routing Problem with Time Windows and Vehicle Synchronization, where deliveries are carried out by smaller low- or zero-emission vehicles as well as larger trucks. Given their capacity restrictions, the smaller vehicles can only deliver small-sized orders and have to be replenished via depot locations or the larger-sized trucks. Beside replenishing smaller vehicles at satellite locations, larger-sized trucks can deliver both small-sized orders as well as larger items. Managing these two types of fleets in an urban setting under consideration of capacity limitations, tight delivery time windows, vehicle synchronization and selective order fulfillment is challenging. We model this problem on a time-expanded network and apply network reduction by considering the time window constraints. In addition, we propose a branch-and-price algorithm which is capable of solving instances with up to 200 customers and continuously outperforms a state-of-the-art general purpose optimization solver. Moreover, we present several managerial insights concerning the use of synchronization, vehicles and the placement of depot/satellite locations.