A Labeling Approach for the Electric Vehicle Routing Problem with Truck Driver Scheduling

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Abstract

The electrification of heavy-duty transport introduces new challenges for logistics planning. Aside from regulations regarding truck driver working hours, planners must now also take into account potential range issues or a lack of charging locations associated with electric vehicles (EVs). This extended abstract investigates the Electric Vehicle Routing Problem with Time Windows and Truck Driver Scheduling (EVRTDSP). We introduce a ruin and recreate algorithm coupled with a specialized labeling procedure to verify schedule feasibility.

1 Introduction

The transition to electric trucks is a necessary step toward sustainable logistics. However, this shift complicates the already difficult task of vehicle routing. While internal combustion vehicles offer long ranges and negligible refueling times, EVs are constrained by a limited battery capacity and a sparse charging infrastructure. Consequently, the traditional assumption that a driver can refuel and rest at any convenient location is no longer valid. Moreover, synchronizing the scheduling of charging sessions with the break and rest periods for drivers as mandated by the European Union Regulation (EC) No. 561/2006 becomes necessary to maintain efficiency. This results in a highly constrained problem: stops for charging and major breaks must occur at designated stations and are ideally synchronized whenever possible. This paper proposes a method to find a solution for this combined problem, aiming to minimize the number of vehicles and the total distance traveled while ensuring that battery levels and driver regulations are respected.

2 Problem Description

The problem can be described as a weighted graph containing customer locations with time windows, a depot, and a set of auxiliary nodes representing parking and charging stations. The weights of the graph represent travel times. A solution consists of a set of tours where each tour is a sequence of locations visited by an EV. For a tour to be feasible, it must satisfy the following set of constraints:

1. **Customer Constraints:** Service at each customer location must begin within a specified time window. Arriving early is allowed, but the driver must wait until the window opens.
2. **Battery Constraints:** The battery level must never drop below zero. Recharging is only possible at designated station nodes and takes time. Moreover, recharging may be interrupted before the battery is fully charged.
3. **Driver Constraints:** The schedule must comply with EU regulations (e.g., a 45-minute break after 4.5 hours of driving). Moreover, drivers in our model cannot stop on the edges between nodes; they must reach a customer or a designated station to take a break.

Solutions are ranked by the following hierarchical objective: first, minimize the required fleet size, and second, minimize the total distance traveled.

3 Proposed Algorithm

The problem is solved using a ruin and recreate metaheuristic. This approach builds upon the framework successfully applied to the non-electric Vehicle Routing and Truck Driver Scheduling Problem (VRTDSP) by De Walsche et al. [2]. We extend that methodology to handle the constraints introduced by battery management and discrete charging and resting stations.

3.1 Vehicle Routing Strategy

The vehicle routing component utilizes the Slack Induction by String Removals algorithm introduced by Christiaens and Vanden Berghe [1]. In the Ruin phase, we employ string removal and split-string removal operators to eject customers from their current routes. In the Recreate phase, we employ a Best Insertion heuristic to repair the solution.

3.2 Feasibility Checking

Determining the feasibility of a sequence of customers is non-trivial due to the interdependence of charging and break decisions. Before verifying feasibility, the ordered list of customers is transformed into a physical route. We construct a path that minimizes travel distance while ensuring the vehicle passes a sufficient number of auxiliary charging and resting stations to make the route viable.

Once this path is established, we propose a labeling algorithm to verify if a valid schedule exists. The algorithm constructs a decision tree. When the vehicle arrives at a designated station, the label expands into multiple branches: pass through, stop to rest, stop to charge, or a combination of charging and resting. As fully charging the battery may not always be the best choice, we generate branches for varying target battery levels.

To maintain efficiency, we apply label domination. A label is dominated and pruned if another label at the same node has a higher battery level, lower accumulated driving time, and an earlier arrival time.

4 Preliminary Results

The performance of the proposed algorithm is evaluated using modified VRTDSP instances introduced by Goel [3]. These were originally Vehicle Routing Problem with Time Windows (VRP-TW) instances constructed by Solomon [4]. We adapted these instances to the EVRTDSP by introducing battery constraints and a limited set of auxiliary nodes acting as charging and resting stations.

By the time of the conference, we aim to present a sensitivity analysis regarding vehicle specifications. Specifically, we will investigate the trade-off between battery capacity and the minimum required fleet size, identifying scenarios where larger batteries significantly reduce the need for synchronized charging stops.

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