Mixed-Integer Programming Formulations and Valid Inequalities for the Electric Vehicle Routing Problem

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Extended abstract

In recent years, environmental issues like greenhouse gas emissions from vehicles absorbs great attention worldwide. So, many companies start to use Electric Vehicles (EV) to respond to the new concerns. In the literature, Electric Vehicle Routing Problem (E-VRP) is introduced to handle the new challenges of using EVs within the vehicle routing problem (VRP). E-VRP aims to route a fleet of capacitated EVs to serve customers' demands while minimizing the total travel distance, considering battery restrictions, and determining charging stations to visit. To the best of our knowledge, existing studies in the literature do not focus on the emerging E-VRP problem by presenting different Mixed Integer Linear Programming (MILP) formulations and comparing their performances over various-sized instances. Although several works proposed valid inequalities for E-VRP and its variants, a general comparative analysis of their efficiency with the previous ones has been rarely studied. Hence, the present work fills these gaps by providing different MILP formulations for E-VRP and valid inequalities for each E-VRP formulation by modifying the existing formulations in capacitated VRP (CVRP) and Green VRP (G-VRP) literature. The contributions of this work are listed as follows:

- We present four MILP formulations tailored for the E-VRP problem with charging stations and capacitated vehicles with different sets of decision variables.
- We provide four valid inequalities to strengthen the formulations of E-VRP.
- We compare the performances of the E-VRP formulations in terms of reaching a better objective function at a constant execution time over various instances.

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– We analyze the performances of the valid inequalities in terms of Linear Programming (LP)-bound, number of explored nodes in Branch-and-Branch (B&B) tree, and execution time.

The first three models are based on the Miller-Tucker-Zemlin constraints, and the fourth one is based on the flow variables. Also, the valid inequalities are derived from the VRP and G-VRP literature, and then modified to be E-VRP valid constraints. For computational experiments, various-sized instances with 15 to 100 customers and 5 to 21 charging stations are chosen from the literature. 0n average, the fourth model outperforms the others in terms of execution time on instances with 15 customers. On the other hand, for large-scale instances with 100 customers, no significant difference is observed among different formulations. Additionally, the results confirm the effectiveness of the valid inequalities as their addition to the original formulations improves LP-bound, and explores less nodes on B&B tree with lower computational time. Among valid inequalities, the results indicate that the second, third and fourth valid inequalities have better performance than the first one in these aspects. For future studies, new strong valid inequalities and efficient MILP formulations can be presented for E-VRP or its variants while further investigating their theoretical properties.

Keywords: Electric vehicle routing problem, Mixed-Integer linear programming formulations, Valid inequalities