**First stage formulation – Facility Location Strategic Problem**

Parameters:

Variables:

Formulation:

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**First stage formulation – Facility Location Strategic Problem – Other formulation**

Parameters:

Variables:

Formulation:

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**Second stage formulation – Vehicle Scheduling Operational Problem**

Parameters



Variables

Formulation:

Minimize driving and charging cost, plus total waiting time.

1. If is assigned to , must recharge once
2. Every vehicle must be assigned to one station
3. Each vehicle can only be assigned to reachable stations
4. For any time period, at most   vehicles charging and waiting in line at station
5. A vehicle can either be waiting in line or recharging
6. If assigned to , must recharge for time periods
7. Consecutive recharging constraint
8. Consecutive waiting constraint

9. FIFO

1. Variables’ nature

**Second Stage Cute Formulation**

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**Second Stage Dantzig-Wolfe Decomposition Formulation**

We have a set of vehicles and a set of vehicles , as well as a discrete planning horizon .

In the second stage problem, we must assign every vehicle to a charging station . Using a column generation scheme, we can understand the problem as a scheduling problem for each station , where we must guarantee that each vehicle is assigned to exactly one of them. So, for each station , we have a set of feasible charging schedules , where .

A feasible schedule for a given station is one in which every assigned vehicle can recharge consecutively up until full battery level (250 miles), charging and waiting line capacities are not violated and FIFO service is guaranteed among assigned vehicles.

For each vehicle we define a subset of stations with all the stations that it can be assigned to. That is, all stations for which the vehicle has enough range to drive to and enough time to recharge until full battery level from the moment it arrives at the station.

Finally, we define:

We use Dantzig-Wolfe’s decomposition to iteratively generate attractive feasible schedules for each station in terms of their reduced cost. So for each station we restrict the subset of feasible schedules to .

**Restricted Master Problem:**

Parameters:

Formulation:

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The objective function (1.1) minimizes the total driving and charging cost, with a penalization cost for each vehicle that cannot be assigned to a station, captured by slack variable . Constraints (1.2) ensure that every vehicle is assigned to a station. Constraints (1.3) are the convexity constraints for each station.

Reduced cost:

We have independent subproblems, one for each station . The reduced cost of a schedule for station is:

Subproblem (of a given station ):

Decision Variables:

Formulation:

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Since Dantzig-Wolfe’s decomposition in sadly impractical, we proceed to reformulate the subproblem as a Shortest Path Problem to solve it using a labeling algorithm w/ dominance rules. To achieve this, the RMP is slightly reformulated.

**RMP reformulation for the SPRRC subproblem approach**

We are going to refer to the generated columns of a given station as *routes,* instead of *schedules*. The biggest change in the following model is that each routeis that of a single charger of a station, not of the whole station. This way, for each station the RMP will choose routes among its generated routes .

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This new formulation assumes an individual queue for each charger in a station, instead of a single queue for the entire station. This can weaken the solution in terms of the FIFO policy that the previous formulation followed for each station as a whole. However, the FIFO policy will still be followed on a single charger basis.

**Pricing Subproblem reformulation as a SPPRC**

Vertices attributes:

Arc attributes:

Labelling:

Update: