Public Chargers for Electric Semis: A bi-level Optimization Approach

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Electrifying long-haul freight hinges on deploying high-power chargers where fleets actually travel, yet most carriers cannot individually justify the capital or utilization risk of dedicated infrastructure. We model the required coordination as a bi-level principal–agent framework tailored to the I-10 corridor. In the upper level, a third-party developer (principal) selects candidate hub locations, sizes each site's charger array, and sets location-specific energy tariffs subject to contractual service guarantees on congestion and availability. In the lower level, multiple fleet operators (agents) solve continuous route-and-charge decisions that embed state-of-charge dynamics, heterogeneous values of time, and queueing-based waiting times. The principal's investment and pricing choices and the agents' operational responses are mutually dependent through congestion and energy demand, producing an optimization that links infrastructure decisions with day-to-day logistics behavior.

To navigate this coupling, we design an iterative bilevel decomposition: the principal's discrete-continuous planning problem is solved, holding congestion surrogates fixed; agents then independently update their optimal routing and charging strategies given the current hub design and prices; refined congestion estimates feed back to the principal stage, and the process repeats until decisions and congestion estimates stabilize. This approach preserves tractability while capturing the essential feedback loop among facility sizing, tariffs, and fleet routing.

The framework reveals how service-level guarantees, differentiated pricing, and modest charger utilizations can jointly align developer profitability with fleet welfare, thereby enabling coalition-based charging hubs without requiring each participant to bear full capital risk. Though calibrated to I-10, the model readily extends to broader corridor networks and evolving megawatt-scale technologies.