MIT Climate & Sustainability Consortium

Optimization and collaboration toward a scalable charging infrastructure in logistics

Project Overview

How can electric vehicle routing and charging be optimized to improve the efficiency and reliability of electrified logistics operations?

The growing adoption of electric vehicles introduces new challenges for logistics operations, as limited battery capacity and charging requirements must be incorporated into vehicle routing decisions. This project focuses on the Electric Vehicle Routing Problem with Time Windows and Nonlinear Charging (EVRPTWNL), which requires determining vehicle routes and schedules while accounting for customer time windows, vehicle capacity, battery limitations, and charging decisions.

The team of this project includes Alexandre Jacquillat, associate professor of operations research and statistics at the MIT Sloan School of Management; and Sean Lo, PhD Candidate in Operations Research at MIT. The team develops a new column-generation approach that separates routing into sub paths between depots and charging stations, allowing charging decisions to be incorporated efficiently. The researchers use a two-phase label-setting algorithm and a new domination framework to solve the resulting problem. Computational results demonstrate that the approach can improve solution times and scale to larger instances with up to 100 customers.

This project aligns closely with the MCSC's Tough Transportation pathway.

*All MCSC Seed Awards projects and descriptions are available on the MCSC website.

Findings & Outcomes

Better coordination of routing, scheduling, and charging can help organizations overcome operational barriers to electrification and make electric fleets more efficient and reliable.

The approach is tested across several applications, including regional distribution, industrial logistics, last-mile delivery, and robotic fleet management. Results show that the proposed method can find high-quality solutions faster than traditional approaches, with the greatest improvements occurring when vehicles have smaller batteries, longer routes, wider time windows, or need to make multiple charging stops.

While electrification can reduce reliance on costly energy sources, charging requirements can also reduce vehicle availability and make operations more difficult to manage. The researchers address this challenge by studying how electric vehicles can be efficiently routed and scheduled while accounting for factors such as vehicle capacity, customer time windows, battery limitations, and nonlinear charging.

Key Findings Include:

- Decisions about **which tasks vehicles perform, the order of those tasks, and when vehicles recharge** are closely connected and should be optimized jointly.
- **The new approach is more computationally efficient.** The sub path-based method improves both **solution quality and computational time** compared with traditional path-based approaches.
- The approach performs especially well when vehicles have **smaller battery capacities, longer routes, wider time windows, and more frequent charging stops**.
- The framework can support applications such as **middle-mile distribution, industrial vehicles, last-mile delivery, and autonomous robotic fleets**.
- The approach can solve otherwise difficult instances with **up to 100 customers**, making it potentially useful for real-world electric fleet management.

The teams' findings were published in a preprint article on arXiv titled "Subpath-Based Column Generation for Electric Vehicle Routing Problems." This piece demonstrates the importance of integrating routing and charging decisions for electric vehicles, providing new evidence that efficient electrified logistics requires coordinated approaches to transportation and energy management.

Opportunities for Implementation

This project contributes to new algorithms in large-scale optimization and mechanism design. Companies could pilot the research by applying the optimization model to a small portion of their electric fleet to improve vehicle assignments, routing, and charging schedules. The researchers' work shows improvements in solution quality and computational time, while its applications in middle-mile, industrial, and last-mile logistics demonstrate its potential across different operating environments. Companies could use these results to evaluate operational benefits and, if successful, scale the approach to larger fleets and inform future charging infrastructure investments. The project also creates opportunities for MCSC members to engage with the research through deployment, pilot applications, and follow-up work that can help translate the algorithms and findings into practical tools for fleet electrification. More broadly, this research can contribute to new tools and policy recommendations that support the ongoing transition toward the electrification and decarbonization of long-haul logistics.