Energy-Aware Route Planning with RouteE Compass

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ABSTRACT

This poster introduces RouteE Compass, a new tool that advances sustainable transportation by enabling energy-aware route planning across diverse vehicle types and large-scale road networks. By addressing practical trade-offs between energy consumption, travel time, and economic cost, RouteE Compass fills critical gaps in traditional routing methods, which often lack the flexibility to prioritize energy directly. The tool's scalability and high-performance computing capabilities allow for national-scale analyses, offering actionable insights for fleet operators, transit agencies, and researchers. As an open-source, extensible platform, RouteE Compass empowers ongoing research and innovation in energy-aware routing, supporting the broader goals of reducing emissions and enhancing transportation sustainability.

ENERGY-AWARE ROUTE PLANNER

- **Limitation of Traditional Eco-Routing:** Conventional eco-routing methods may prioritize energy reductions alone ("energy-optimal"), which often sacrifice practicality. Other existing methods rely on ranking pre-defined routes ("eco-scoring") that fail to discover a true balance between critical factors like time, distance and cost.
- **Introducing RouteE Compass:** RouteE Compass is a new open-source tool that enables dynamic balancing of energy, time, distance and economic cost to address real-world trade-offs with a customizable utility function tailored to diverse routing priorities.
- **Powered by Robust Models:** Built on the RouteE Powertrain library [1], RouteE Compass uses mesoscopic vehicle energy prediction models grounded in real-world driving data.
- **Advanced Routing Capabilities:** Integrates energy estimation directly into the search cost function while independently modeling vehicle states like battery charge and time-of-day speeds.
- **Scalable & Efficient Design:** Written in Rust, RouteE Compass uses a parallel architecture and memory-efficient data structures to process large-scale graphs with over 100 million edges on local or high-performance systems.

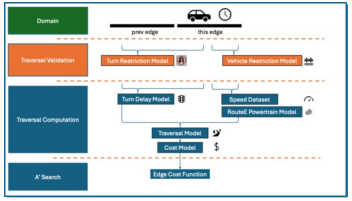

Figure 1: Link-Level Econometric & Mechatronic Modeling

PATH-LEVEL IMPACTS

- **Objective:** Compare RouteE Compass "eco-scoring" and "energy-aware" algorithms for trip optimization. The goal is to evaluate differences in route selection for local and regional trips using distinct optimization approaches.
- **Algorithms Explored:** Eco-scoring uses two variants of the k-shortest paths (KSP) algorithm [2], one weighted by distance and the other by time, while energy-aware routing uses the RouteE Compass cost model to approximate the Pareto-optimal front of route alternatives based on energy cost weights.
- **Example Trips:** National results were reviewed to identify local (5–50 miles) and regional (50–500 miles) trips with notable differences between time-optimal and energy-optimal routes. From these, two origin/destination pairs showing time-energy trade-offs were randomly chosen.
- **Key Observations:** Eco-scoring struggles to estimate the Pareto front effectively, even after 200 iterations. In contrast, energy-aware routing produces a smooth Pareto curve with clear time-energy trade-offs.

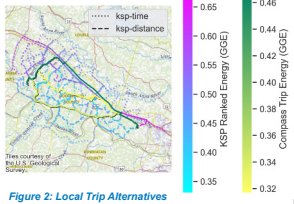

Figure 2: Local Trip Alternatives

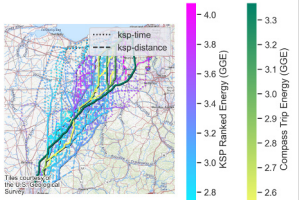

Figure 3: Regional Trip Alternatives

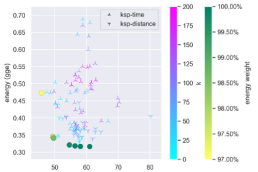

Figure 4: Local Tradeoffs

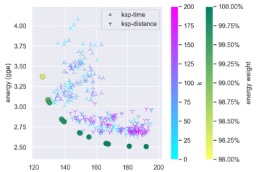

Figure 5: Regional Tradeoffs

NATIONAL-LEVEL IMPACTS

- **Large-Scale Dataset:** Evaluated energy savings potential using 25 million trips within the continental US, run over a grid of energy weights and powertrain technologies including an Internal Combustion Engine Vehicle (ICEV), a Hybrid Electric Vehicle (HEV), and a Battery Electric Vehicle (BEV). This large-scale analysis generated 4.66 billion routing queries.
- **Powertrain Differences:** Results highlight significant differences between powertrain technologies, especially as energy weights approach a value of 1. Notably, BEV's achieve significant potential energy savings with large time penalties.
- **Realistic Savings:** Each powertrain exhibits non-negligible energy-savings at low time penalties.

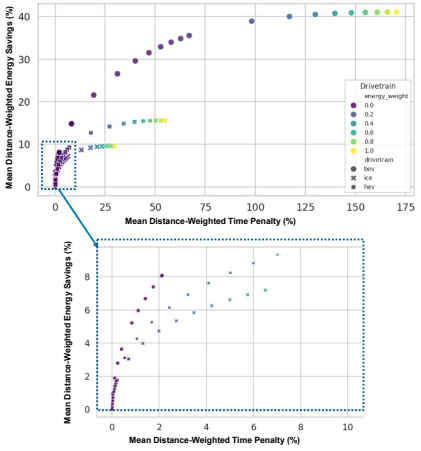

Figure 6: National Tradeoffs

HIGHLIGHTS

- **New Research Tool:** RouteE Compass is a new open-source route planning tool that balances energy consumption with other considerations like travel time and cost. By exploring trade-offs between these factors, it offers insights into routes that reduce energy while also minimizing cost and time. This makes it especially valuable for fleet operators, transit agencies, and researchers focused on reducing energy consumption, emissions and operating costs.
- **Proven Scalability and Impact:** Demonstrated through a national-scale study with over 4.66 billion queries over 150 HPC compute nodes, RouteE Compass is capable of large-scale analyses. Moreover, the study exposed the variability among powertrain technologies and highlighted the potential for energy-aware routing to achieve significant savings and emission reductions.
- **Future-Focused and Extensible:** With a modular design and flexibility to accommodate evolving routing priorities, RouteE Compass is set up for extension to consider multimodal networks, integration of EV charging infrastructure and inclusion of additional factors like emissions and congestion.

REFERENCES AND LINKS

[1] National Renewable Energy Laboratory (NREL), RouteE Powertrain. https://github.com/NREL/routee-powertrain, 2024.

[2] Abraham, I., D. Delling, A. V. Goldberg, and R. F. Werneck, *Alternative routes in road networks*. Journal of Experimental Algorithmics (JEA), Vol. 18, 2013, pp. 1–1.

Source Code

RouteE

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