On Accessibility Fairness in Intermodal Autonomous Mobility-on-Demand Systems

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Abstract: This work proposes a novel optimization framework for the planning of intermodal Autonomous Mobility-on-Demand (I-AMoD) systems, with a particular emphasis on accessibility fairness—a dimension often neglected in engineering-focused mobility research. Departing from traditional optimization goals such as minimizing travel time, this work introduces socially beneficial criteria—especially equity and accessibility—into the operational decision-making of mobility systems. It bridges the gap between quantitative transport engineering approaches and the qualitative justice-oriented concerns raised in social science, advocating for a more equitable distribution of access to mobility services.

1. INTRODUCTION

With the advent of autonomous vehicles, interconnected transport networks, and the rise of Mobility-as-a-Service (MaaS), cities face new challenges and opportunities in reshaping their urban transport systems. However, the benefits of these technological shifts are unevenly distributed. Current planning of Autonomous Mobility-on-Demand (AMoD) systems predominantly aims to improve efficiency, often neglecting equity concerns like geographic or social exclusion (Salazar et al. (2024)). This work reframes the planning problem to explicitly incorporate accessibility fairness, addressing the lack of operational models that measure and correct accessibility shortfalls.

2. METHODOLOGY

This work models a multi-layer intermodal transport network comprising walking, biking, public transport, and AMoD car layers, integrated via transfer nodes. Multiple optimization frameworks are proposed:

(1) Minimum Travel Time: Traditional linear programming model focused solely on reducing average travel time (Salazar et al. (2020)).
(2) Minimum Commute Accessibility Unfairness: Introduces a convex Quadratic Program (QP) where accessibility shortfalls are penalized, based on the idea that repeated commutes exceeding a reasonable time threshold reduce overall fairness.
(3) Minimum Trip Accessibility Unfairness: This framework uses a Linear Program (LP) to penalize individual trips that exceed a predefined time threshold, ensuring that each trip, rather than just the average, aligns with accessibility standards.
(4) Minimum Destination Accessibility Unfairness: This approach employs a Mixed Integer Linear Program (MILP) to enforce a sufficiency threshold on the number of destinations that must be reachable within a region, where accessibility is defined by a specified travel time limit. Based on sufficientarianism theory, the framework seeks to guarantee a basic standard of mobility for all (Martens (2017)).

All formulations are applied to a case study of Eindhoven, The Netherlands, using its transport infrastructure data and simulated travel demand.

3. RESULTS

Key findings in this work include:

Accessibility fairness can be significantly improved with minimal compromise on efficiency. For instance, prioritizing accessibility fairness increased the average travel time of the population by only 0.12 minutes while drastically reducing inaccessibility for underserved OD-pairs (Fig. 1).

Trip-based accessibility fairness optimization offers better individual-level fairness, although at slightly higher average travel time (Fig. 2).

The destination sufficiency-based model ensures regional balance in access to destinations, offering a scalable policy tool for identifying and correcting mobility disparities on a regional level.

Resource allocation (e.g., vehicle usage) shifts significantly under fairness-optimized models, with AMoD vehicles being prioritized for longer or underserved trips, and active modes (e.g., biking or walking) and public transport allocated for short trips.

4. CONCLUSION

This work demonstrates that integrating accessibility fairness into AMoD system planning is not only feasible but crucial for achieving socially just urban mobility. By providing rigorous, scalable optimization tools that go beyond traditional efficiency metrics, this work lays the groundwork for a new paradigm where access to mobility is a right, not a privilege.

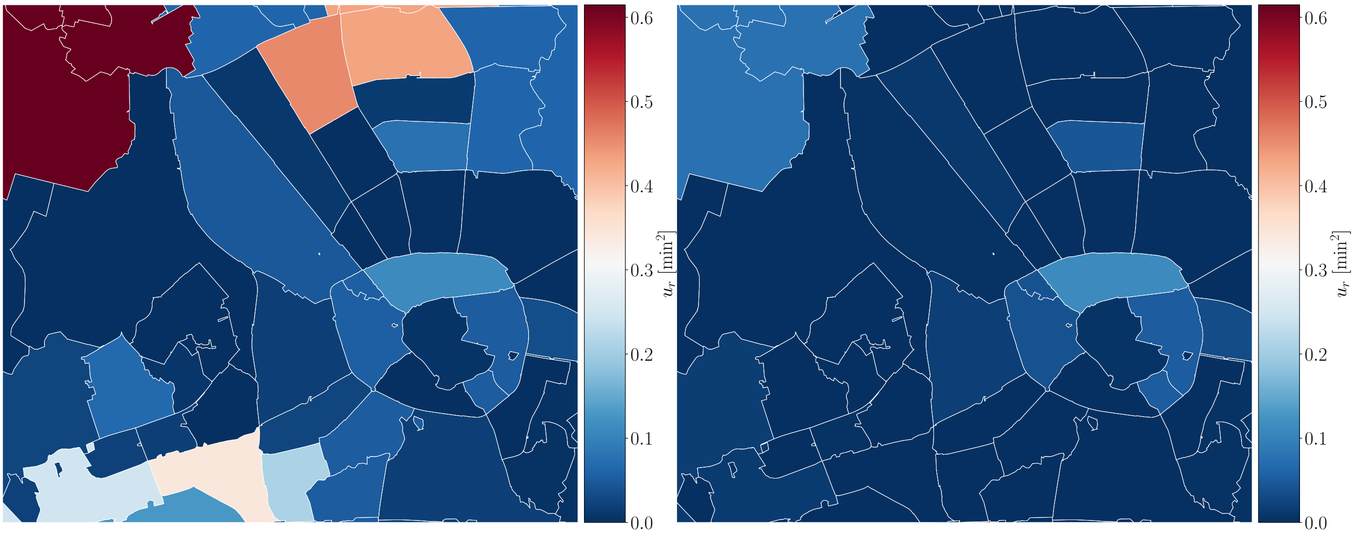

Fig. 1. Commute-accessibility-unfairness levels in the PC4 regions of Eindhoven, NL, for the objective of minimizing travel-time (left) and minimizing commute-accessibility-unfairness (right).

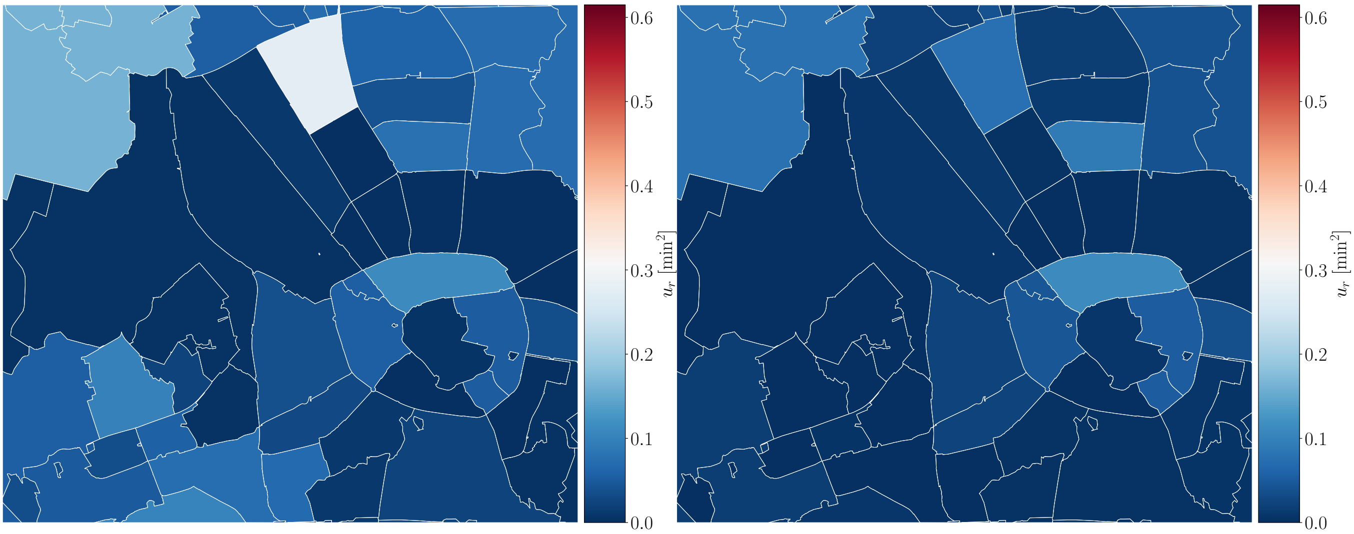

Fig. 2. Path-accessibility-unfairness levels in the PC4 regions of Eindhoven, NL, for the objective of minimizing commute-accessibility-unfairness (left) and minimizing trip-accessibility-unfairness (right).

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