IMPROVING REACHABILITY DENSITY METRIC IN MOD SERVICES THROUGH NETWORK KERNEL DENSITY ESTIMATION

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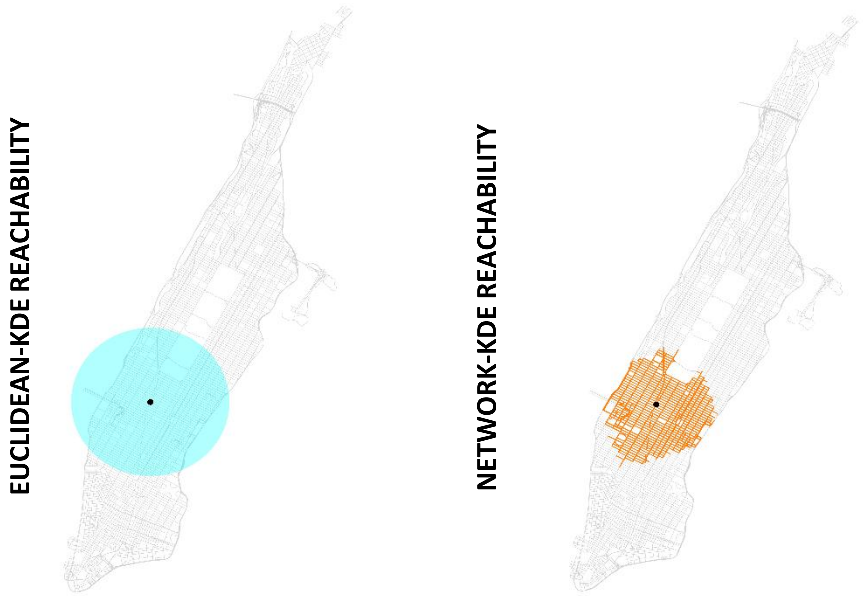
Problem:

Current AMoD dispatch solvers rely on straight-line, planar distances that ignore physical urban barriers. This creates a phenomenon of “**false reachability**" causing systems to artificially overestimate vehicle supply and misallocate idle fleets.

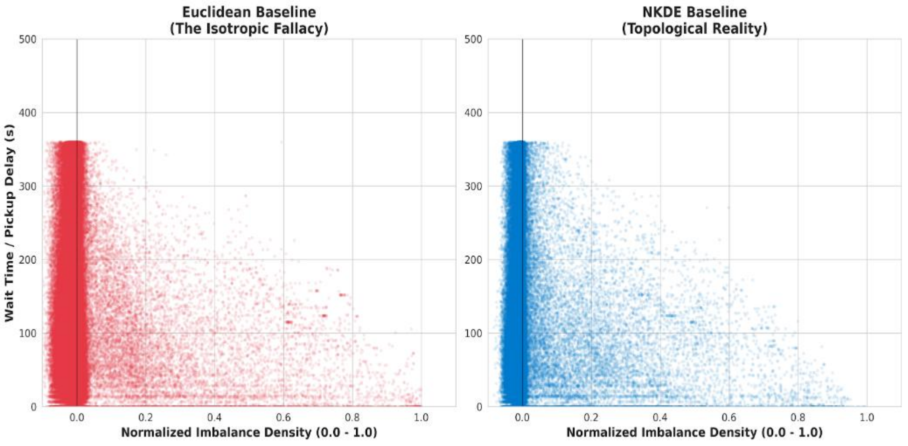


Objectives:

Formulate: Develop a Network-Aware Reachability Density Metric (RDM) using actual road topologies (NKDE).

Integrate: Derive a topological correlation matrix **(F2)** to power a network-aware repositioning optimizer.

Benchmark: Evaluate the strategy in FleetPy to minimize empty vehicle miles (VKT) and customer wait times.



Empirical correlation between Imbalance Density and Pickup Delay. The planar model (left) drastically overestimates reachable supply near urban obstructions, whereas the NKDE metric (right) tightly correlates with actual topological fleet availability.

Methodology:

1. Baseline Density Comparison: Evaluates fleet reachability by comparing standard Euclidean KDE, which assumes unrestricted isotropic travel, against the proposed Network KDE (NKDE). The NKDE framework executes via a 3-stage computational pipeline: spatial discretization, reachability matrix formulation, and dynamic state integration. This model strictly confines density calculations to the drivable road network, discretizing paths into 50 m "lixels" and bounding reachability by a 360 s maximum wait time.

2. Active Fleet Repositioning: To correct spatial imbalances, an **(F2)** Topological Correlation Matrix was formulated to map the exact spatial overlap of vehicle reachability between interconnected zones. A Mixed-Integer Programming (MIP) solver then actively routes the idle fleet, prioritizing optimal service density before minimizing empty vehicle miles.

Results & Impact:

System Recovery: A passive fleet structurally collapses, yielding a severe **62.15%** service rate. The active NKDE framework restored system health, achieving a **95.17%** absolute service rate.

Imbalance Reduction: The network-aware controller decreased the average absolute systemic spatial imbalance ***(Kabs)*** by a massive **60.1%.**

Route Thrashing Eliminated: By understanding exact topological proximity, the NKDE model successfully suppressed redundant, energy-intensive border crossings.

Operational Efficiency: It required **29.8%** fewer empty repositioning trips than traditional disjointed models. This cut nearly **8,900** deadhead routes while maintaining elite passenger throughput.