Non-myopic pathfinding for shared-ride vehicles: A bi-criteria best-path approach considering travel time and proximity to demand

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Project Objective

The overarching goal of this research project is to improve the operational efficiency of shared-ride mobility-on-demand services (SRMoDS) like UberPool and Lyft Line, in order to increase vehicle occupancies and decrease vehicle mileage. To meet this goal, the objective of this study is to develop a network pathfinding algorithm that considers both a network path's travel time and its proximity to potential future demand (i.e., travel requests), as opposed to a conventional shortest path algorithm that solely considers travel time.

Figure 1 provides an illustrative example that compares the shortest path approach with the bi-criteria approach that considers travel time *and* proximity to demand. Notably, the shortest path approach immediately moves the vehicle from user 1's pickup location to the low-demand region with short travel time links. Conversely, the bi-criteria approach moves the vehicle through the moderate demand area, near the high demand area, on links that have slightly longer travel times.

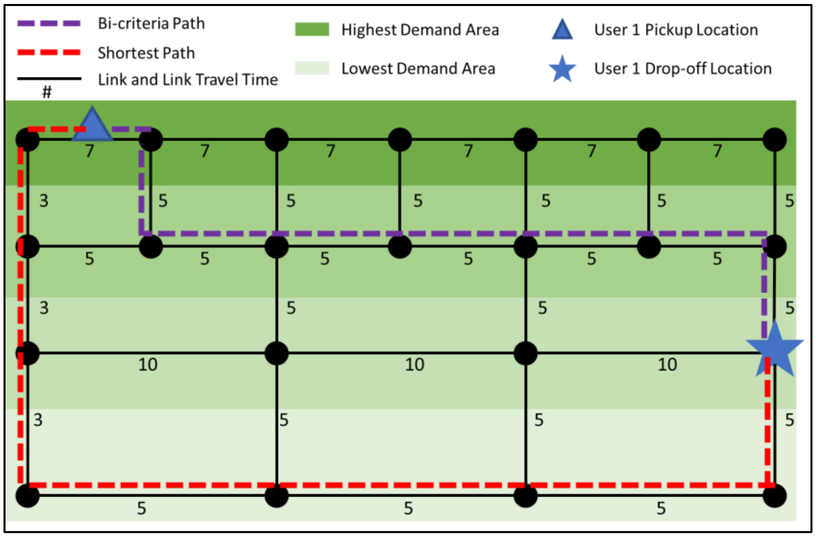

Figure 1: Paths for shortest path (red) and bi-criteria (purple) strategies

The research project effectively tests the hypothesis that assigning vehicles to paths considering proximity to potential future demand, in addition to travel time, will improve the operational efficiency of a SRMoDS compared to assigning vehicles to shortest travel time paths. Improving operational efficiency in this study entails reducing a weighted combination of user wait times, user in-vehicle travel times, and total vehicle miles traveled across the fleet.

Problem Statement

The SRMoDS operational problem is characterized by a fleet of m vehicles that aim to serve n customers who request service during a finite period (e.g., 3 hours, 12 hours, 24 hours) in a transportation network composed of links (i.e., road segments) and nodes (i.e., intersections). Using the fleet of m vehicles, the SRMoDS operator must pick up travelers at their requested pickup locations and drop them off at their requested drop-off locations in the network. However, each vehicle can pick up and drop off other users, as it travels between the pickup and drop-off locations of the original traveler.

To serve a set of traveler requests in real-time, the SRMoDS operator needs to address the following operational subproblems: (a) matching vehicles to travelers, (b) sequencing traveler pickup and drop-off tasks for individual vehicles, (c) repositioning empty vehicles to balance supply and future demand, and (d) assigning vehicles to network paths.

Research Methodology

To address operational subproblems (a-c), this study applies state-of-the-art operational strategies, models, and algorithms (*1*, *2*). However, while the existing literature assigns vehicles to network paths based solely on travel time, this study proposes an operational policy, model, and algorithm to assign vehicles to network paths considering both travel time and proximity to potential future traveler requests – as shown in Figure 1.

Another key part of the research methodology is the agent-based stochastic dynamic simulation model developed to test the bi-criteria pathfinding approach and compare it to the shortest path approach. The simulation tracks each traveler/passenger agent and each vehicle agent, second by second, as they move through the transportation network. The simulation model also implements the SRMoDS operator's policies that address operational problems (a-d), in real-time.

Figure 2 provides an overview of the proposed operational policies and the overall solution algorithm to solve the SRMoDS operational problem. Every 15-30 seconds in the simulation, the 5 steps displayed in Figure 2 are executed. The SRMoDS operator first needs to determine the location and status of all vehicles as well as the location of all unassigned passenger requests. Then, the operator needs to determine which combinations of traveler requests and vehicles are feasible matches, based on the location of the request and the location, occupancy, and time-window constraints of the vehicle. Next, the operator needs to calculate the cost of the feasible traveler request-vehicle combinations, based on how far the request is from the vehicle and how much the vehicle would need to detour to pick up the request. Steps 1-2 implicitly solve operational subproblem (b). Step 3 involves solving the bi-partite matching problem to assign vehicles to passengers. Step 4 involves repositioning empty or unassigned vehicles. Finally, the last step involves assigning vehicles to network paths, which determines the sequence of nodes or links a vehicle should traverse between its current location and its next assigned pickup, drop-off, or repositioning location.

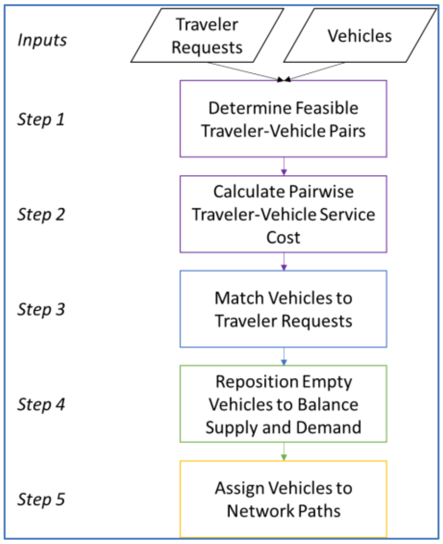

Figure 2: Overview of Solution Approach

Results

The computational results indicate that the bi-criteria approach does outperform the shortest path approach under certain conditions. However, the results indicate a large variance in the difference between the two approaches across scenarios in terms of user wait time, user in-vehicle travel time, and vehicle mileage. Moreover, the average difference between the two approaches is relatively small. Nevertheless, the study does indicate that there is potential for the bi-criteria approach to improve SRMoDS operational efficiency. Moreover, because this is the first study to use a bi-criteria approach, we expect future research to refine the bi-criteria approach and significantly improve its performance relative to the shortest path approach.

The results also indicate that the bi-criteria approach performs best when the system is not heavily oversupplied or undersupplied. Finally, the results indicate that the bi-criteria approach is more effective when the vehicle is currently empty or has one in-vehicle passenger compared to when the vehicle has two or more in-vehicle passengers.