Hierarchical City-Scale Dispatching Method for Ride-Sourcing Systems

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Preliminary Definition

Ride-Sourcing System

Ride-sourcing is an on-demand arrangement where:

- ✓ A driver makes a car available for public hire for passengers
- ✓ a passenger uses a website or app provided by a third party (facilitator) to request a ride, for example Uber, GoCatch, etc.

Dispatching Method

A dispatch method is a way of

- ✓ Allocating passengers to ride-sourcing vehicles (taxis)
- ✓ Transferring vacant ride-sourcing vehicles to the regions with excess of passengers

Problem Statement

Hierarchical City-Scale Dispatching Method for Ride-Sourcing Systems

- ✓ How to assign/match a waiting passenger to vacant ride-sourcing vehicles
- ✓ How to distribute the vacant ride-sourcing vehicles in the network

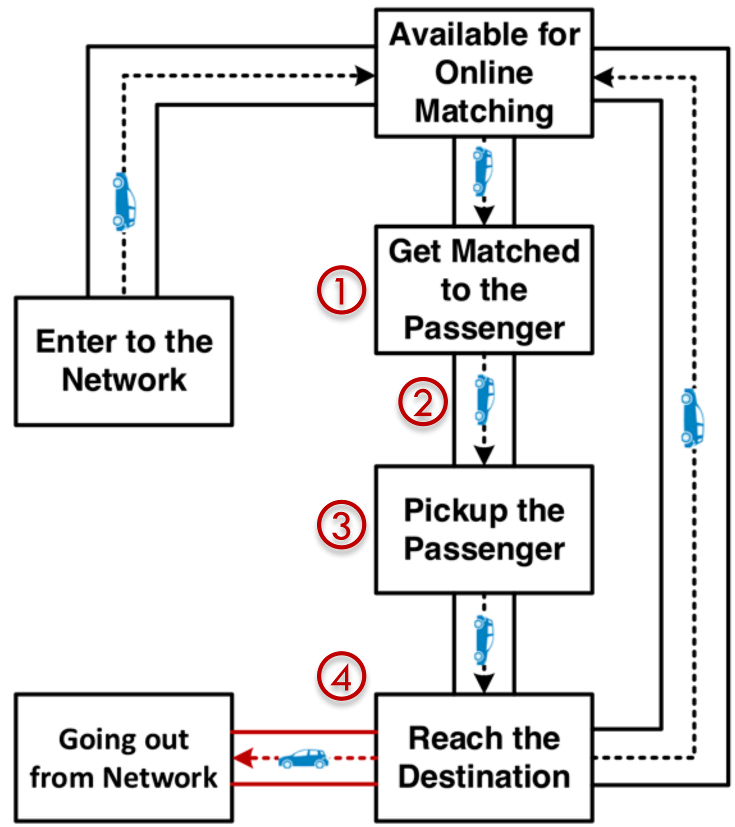
To

- ❑ Reduce passenger waiting time
- ❑ Reduce the trip times
- ❑ Reduce the ride-sourcing vehicles' search time

Introduction

Ride-Sourcing Overview

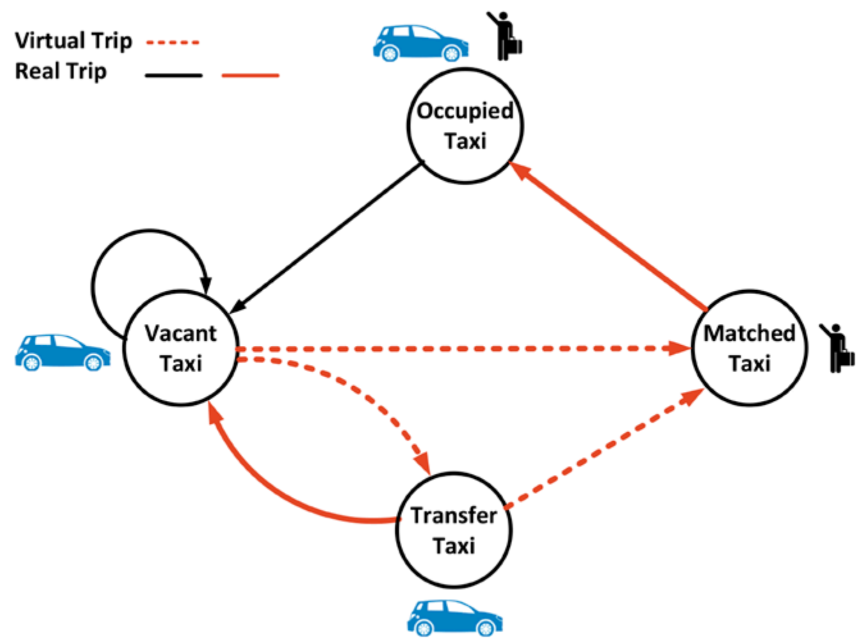
1. An available ride-sourcing vehicle (vacant or transfer) is assigned to a waiting passenger via centralized ride-sourcing system
2. The matched ride-sourcing vehicle cruises towards the matched passenger through the route recommended by the centralized ride-sourcing system.
3. The matched ride-sourcing vehicle reaches to the location (origin) of the matched passenger
4. The occupied ride-sourcing vehicle reach the destination of the passenger then becomes a vacant vehicle or goes out of the network



Introduction

Ride-Sourcing Overview

- ✓ Vacant taxis* are unoccupied taxis cruising within regions
- ✓ Transfer taxis are unoccupied taxis allocated to the regions with an excess of passengers
- ✓ Matched taxis are unoccupied taxis assigned to the matched passenger
- ✓ Once a matched taxi board its matched passenger, the taxi becomes occupied



* Taxis and ride-sourcing vehicles are used interchangeably throughout the presentation

Proposed Dispatching Structure

Plant

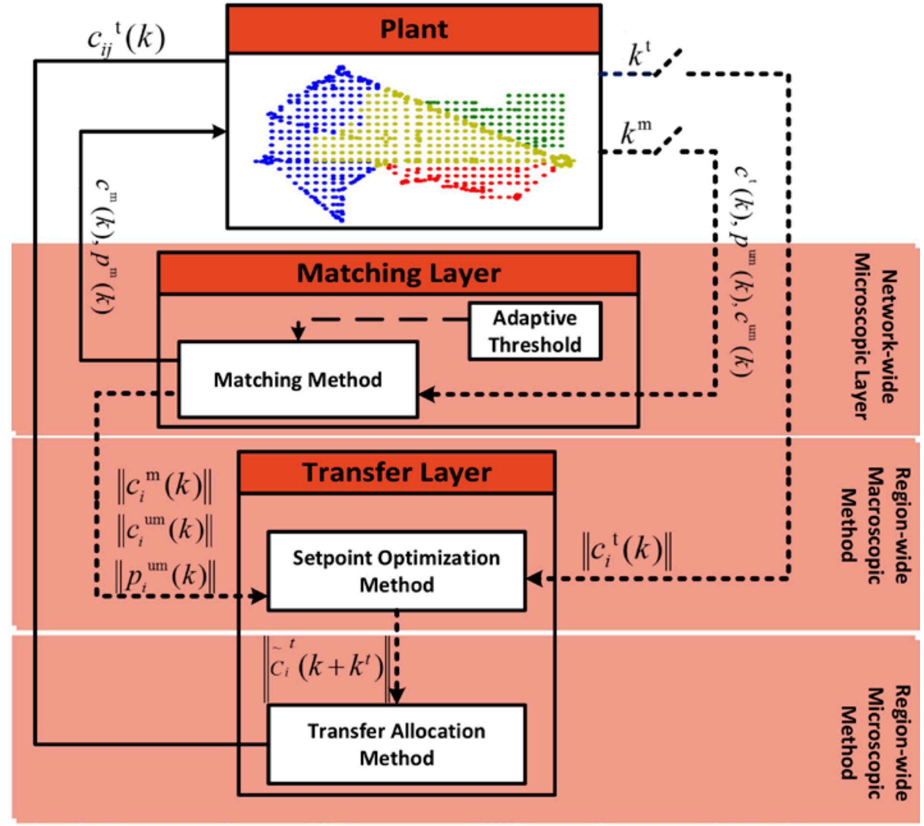
Plant is the real traffic network which is partitioned into different homogenous regions

Matching Layer

Assigns the waiting passengers to the vacant or transfer taxis in each k^{m} sample time

Transfer Layer

Transfers the unmatched taxis to the regions with excess of waiting passengers in each k^{t} sample time



Notation	Variable Name	Notation	Variable Name	Notation	Variable Name
c^{m}	Locations of Matched Taxis	p^{m}	Locations of Matched Passengers	$\|c^{\mathrm{m}}\|$	Number of Matched Taxis
c^{um}	Locations of Unmatched Taxis	p^{um}	Locations of Unmatched Passengers	$\|c^{\mathrm{um}}\|$	Number of Unmatched Taxis
c^{t}	Locations of Transferred Taxis	$\|c^{\mathrm{t}}\|$	Number of Transferred Taxis	$\|\tilde{c}^{\mathrm{t}}\|$	Optimum Number of Transferred Taxis

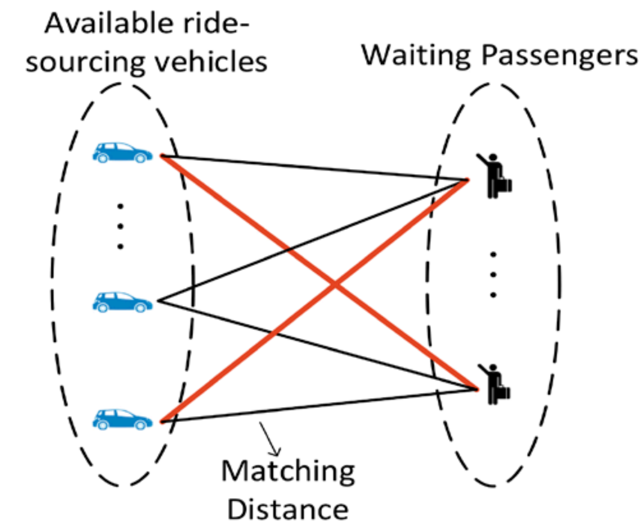
Proposed Dispatching Structure (Matching Layer)

Matching Method

Matching method assigns the waiting passenger to unmatched or transferred taxis to minimize the total matching distance:

$$\min_{e \in E} x_e w(e)\,,$$
$$\text{s.t.} \sum_{e \sim v} x_e \leq 1 \quad \forall v \in \{V_1 \cup V_2\} \;\; \& \;\; x_e \in \{0,1\} \;\forall \in E$$

E as the edges connecting each element of the V_1 to V_2
(V_1 and V_2 are disjoint and independent sets)

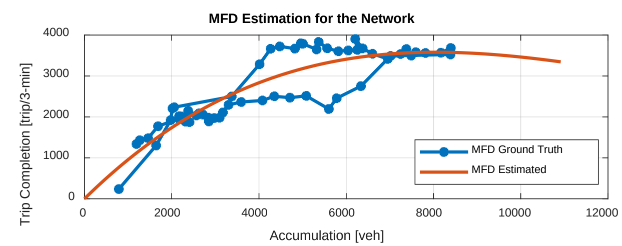


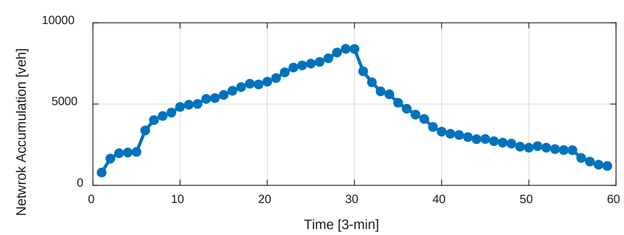
Adaptive Threshold

Adaptive Threshold declines the matchings with excessive pickup distances:

$$\delta(k) = A\left(\frac{\mathrm{v}(k)}{\bar{\rho}}\right)$$

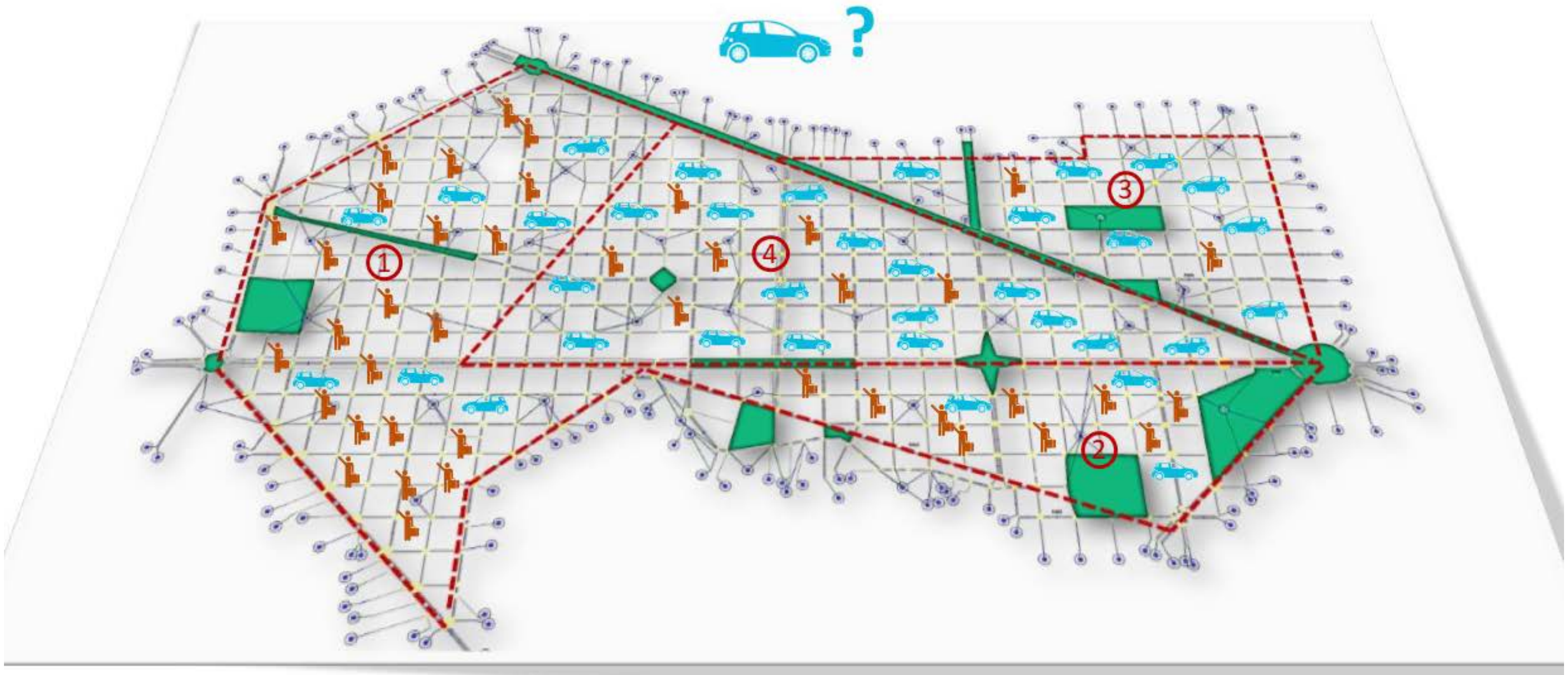
$\mathrm{v}(k)$: network speed
$\bar{\rho}$: average probability for appearance of new travel requests in the network





Proposed Dispatching Structure (Transfer Layer)

Optimization Method:



The optimization method determines the desired number of transferred taxis in region i to maximize the total number of the boarding

Total Number of boarding in region $i \in \{1, \ldots, N\}$

$$\max_{\|\tilde{c}_i^{\mathrm{um}}(k)\|} \left(\sum_{i=1}^{N} \alpha_i \|p_i^{\mathrm{um}}(k)\|^{\beta_i} \left(\|c_i^{\mathrm{m}}(k)\| + \|c_i^{\mathrm{t}}(k)\| + \|\tilde{c}_i^{\mathrm{um}}(k)\| \right)^{\gamma_i} \right)$$

$$\mathrm{s.t.} \sum_{i=1}^{N} \|\tilde{c}_i^{\mathrm{um}}(k)\| = \sum_{i=1}^{N} \|c_i^{\mathrm{um}}(k)\| \quad \& \sum_{i=1}^{N} \|\tilde{c}_i^{\mathrm{um}}(k)\| \geq 0$$

Proposed Dispatching Structure (Transfer Layer)

Transfer Allocation Method:

The allocation methods determines the destination and path of the transferred taxis

$$\min_{e \in E} x_e w(e) \,,$$
$$\text{s.t.} \sum_{e \sim v} x_e \leq 1 \quad \forall v \in \{V_1 \cup V_2\} \;\; \& \;\; x_e \in \{0,1\} \; \forall \in E$$

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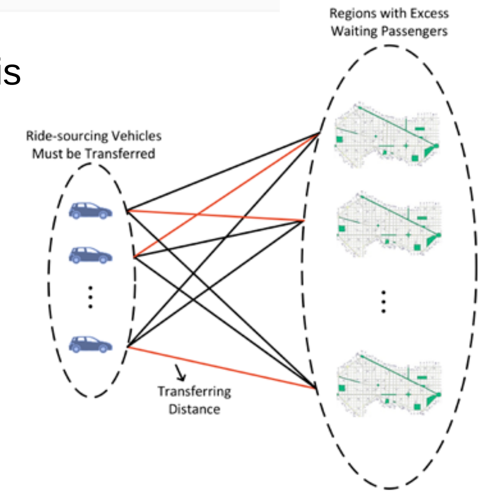
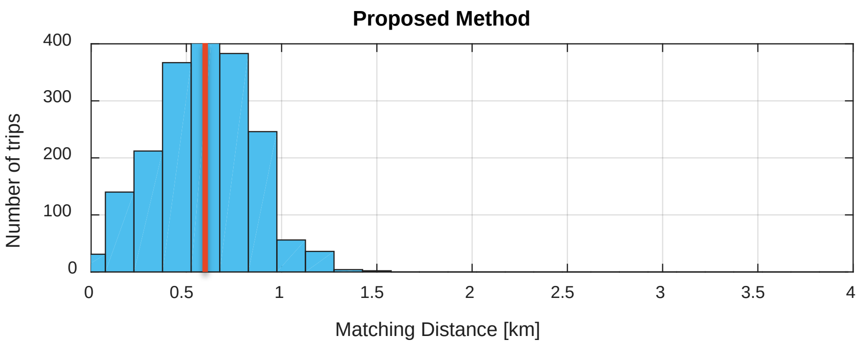
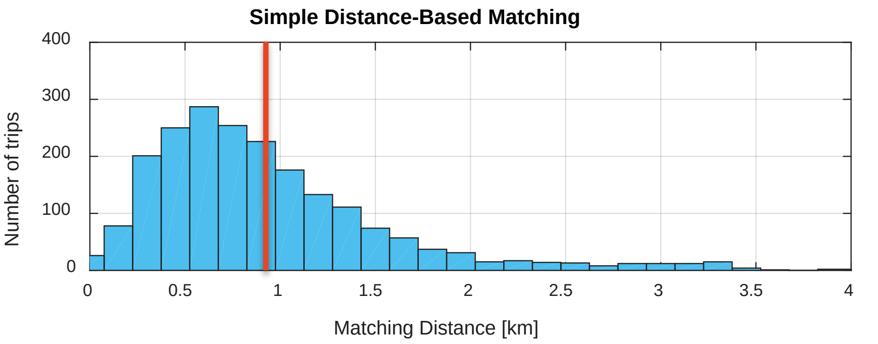
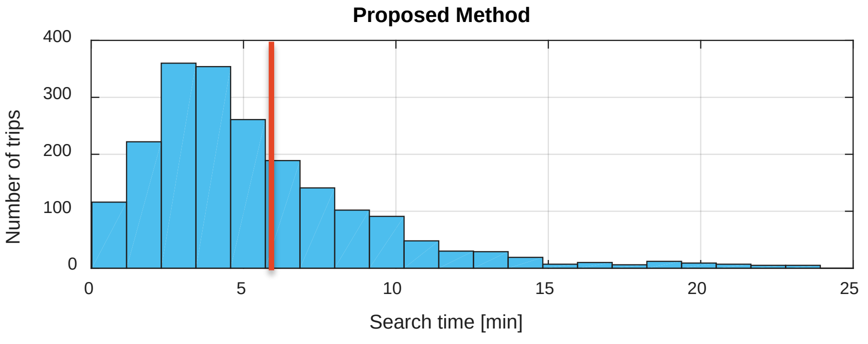
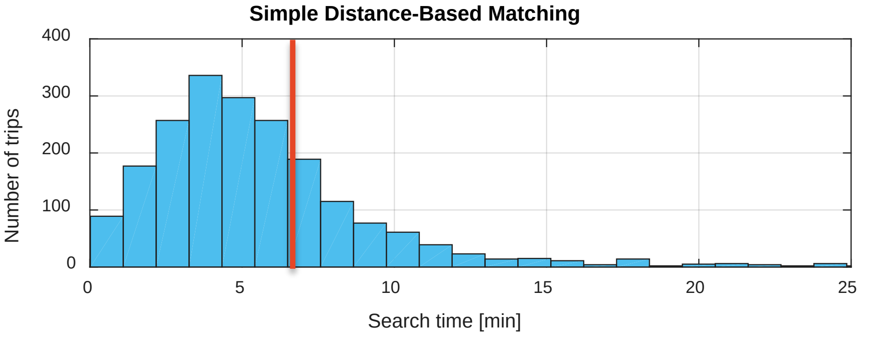


Evaluation (Microsimulation)









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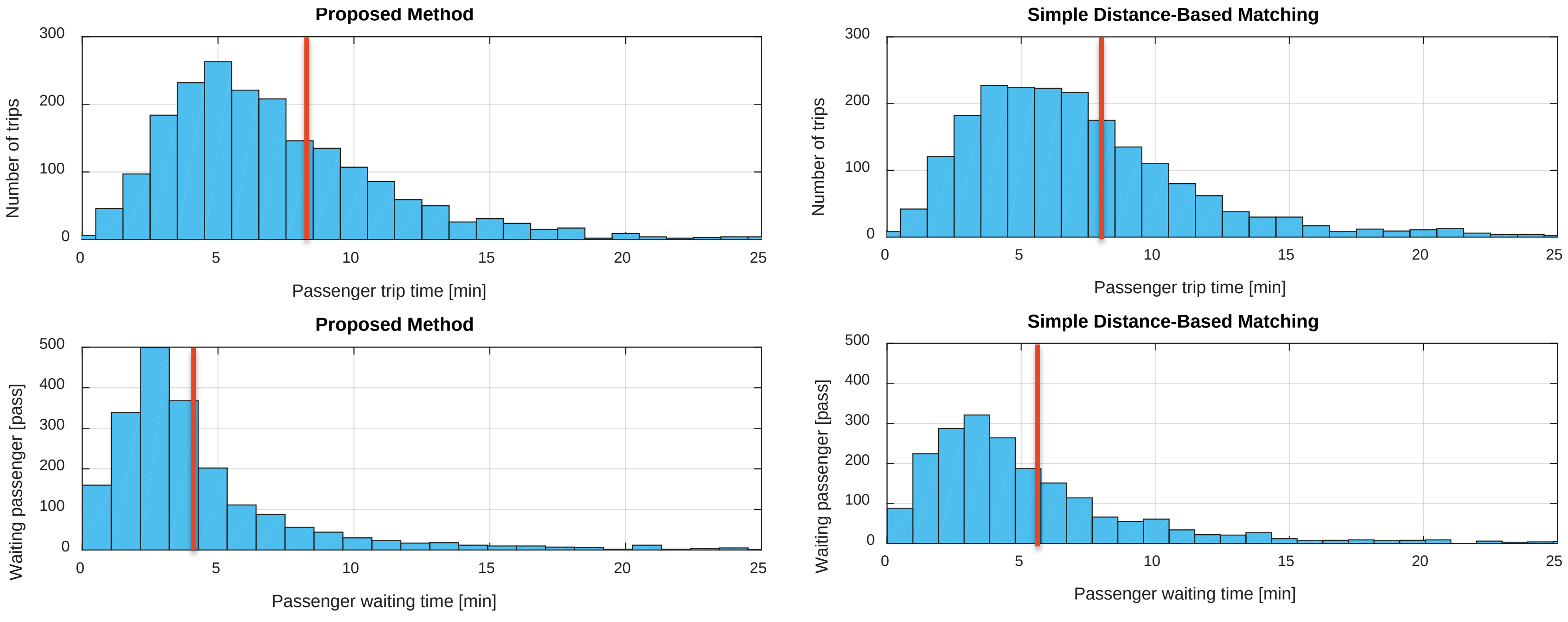

Evaluation (Microsimulation)

	Matching Travel Distance [km]		Search Travel Time [min]		Passenger Trip Time [min]		Passenger Waiting Time [min]	
	Total	Mean	Total	Mean	Total	Mean	Total	Mean
Distance-Based Matching	1916	0.93	13792	6.67	17722	8.58	13107	6.34
Proposed Ride-Sourcing	1214	0.59	12067	5.88	17211	8.38	9802	4.78

Discussion