A Simulation-Based Approach to Compare Policies and Stakeholders' Behaviors for the Ride-Hailing Assignment Problem

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Ride-Hailing

- On-demand transportation system for passengers.

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- Origin and destination.
- Use of GPS, integrated payment.
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DiDi
More than a journey

Impact

- Global market of 57 billion USD in (2021).
- Expected market of 108 billion USD (2025).
- 15 million trips per day (Uber, 2019).
- 30 million trips per day (Didi, 2019).
- Uber and Lyft produce up to 14% vehicle miles driven in some states (The Verge).

Literature review

1. **Forecast demand, then balance it with supply:**
(Moreira-Matias et al. 2013), (Miao et al. 2016), (Xu et al. 2020), . . .
2. **Assigning vehicles to passengers:**
(Souza et al. 2016) → Assignment problem.
(Lowalekar et al. 2016), (Maciejewski et al. 2016) → Two-stage stochastic optimization.
(Alshamsi et al. 2009), (Glaschenko et al. 2009) → Multi-agent simulations.

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   (Alshamsi et al. 2009), (Glaschenko et al. 2009) → Multi-agent simulations.
3. **Strategies to optimize performance: drivers' behaviors**
   (Hoque et al. 2012) → Data analysis to help drivers find passengers.
   (Li et al. 2009), (Henao and Marshall et al. 2019) → Idle time: park or drive?

Goal and Contributions

Goal: Propose different behaviors for drivers while waiting for passengers and compare them with respect to multiple objectives.

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2. We examine the effect of different passengers' arrival conditions on the multiple objectives.
3. We compute and present all results for the multiple objectives on a micro-level, which is novel and allows for better insights and helps to construct better policies.

Model Classes

Driver:

Class Attributes:
- Number of drivers
- Distance driven with passengers
- Distance driven to pick-up passengers
- Distance driven idle
- Number of rides rejected by drivers
- Number of "Roaming events"

Instances Attributes:
- Preferences to accept a ride
- List of arrival events
- List of leaving events
- Capacity
- Luxury Status
- Arrival locations
- Next Roaming Event

Passenger:

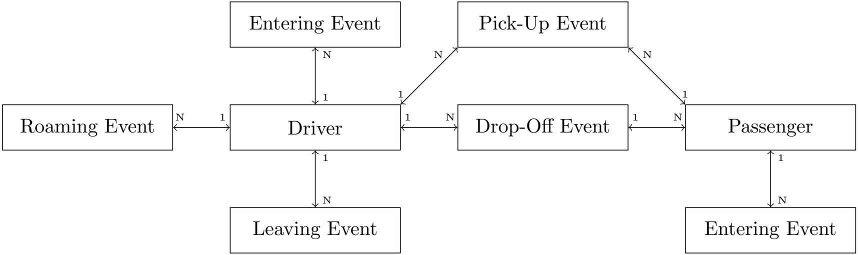
Class Attributes:
- Number of passengers
- Number of accepted drives
- Number of "non-available drivers for ride"
- Number of drives rejected by passengers

Instances Attributes:
- Arrival location
- Destination
- Waiting time preferences
- Capacity needed
- Luxury requirements

MatchingAlgorithm(Passenger,*AvailableDriversList,RoadNetwork):

```
PossibleDrivers = AvailableDriversList;
Times = GetTimes(Passenger,PossibleDrivers,RoadNetwork)
while length(Times) ≥ 1 do
    Index = argmin(Times)
    SelectedDriver = PossibleDrivers[Index]
    if SelectedDriver.MeetsRequirements == True then
        if SelectedDriver.AcceptsRide == True then
            return SelectedDriver, Times[Index]
        end
        else
            Update DriverRejectsRide metric
            PossibleDrivers.Eliminate(SelectedDriver)
            Times.Eliminate(Index)
        end
    end
    else
        Update DriverDoesNotMeetRequirement metric
        PossibleDrivers.Eliminate(SelectedDriver)
        Times.Eliminate(Index)
    end
end
return "No driver meeting requirements is available"
```

Model Events



Roaming Events

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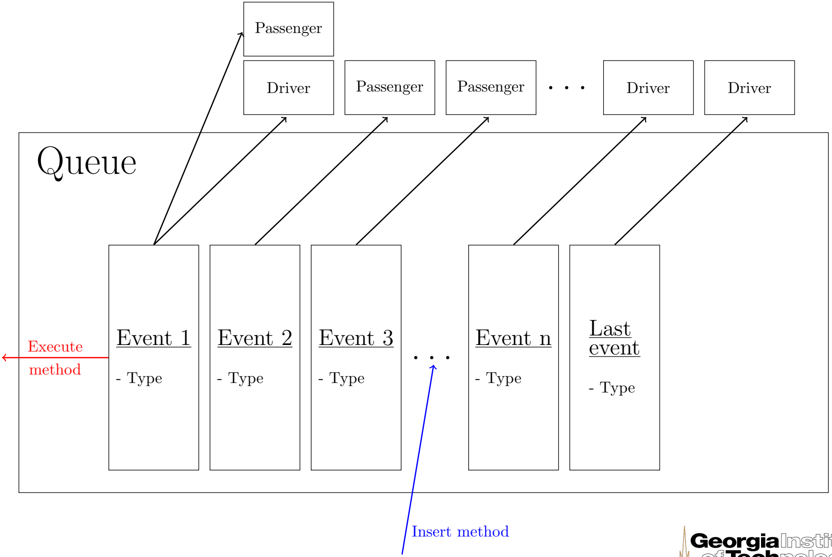
4. **Coordinated hotspot scenario:** Company decides where the driver should go among a list of hotspots.

Queue


Passenger
Driver
Passenger
Passenger
. . .
Driver
Driver
Queue
Execute method
Event 1
- Type
Event 2
- Type
Event 3
- Type
. . .
Event n
- Type
Last event
- Type
Insert method

San Francisco Area

- Top 5 most-populous area in US.
- By the end of 2016 more than 5,700 drivers in peak-hours.
- More than 570,000 miles everyday, more than 170,000 drives, 15% of intra-SF trips (SFCTA 2017)
- Causing 55% average speed decline in the city (Marshall 2018)

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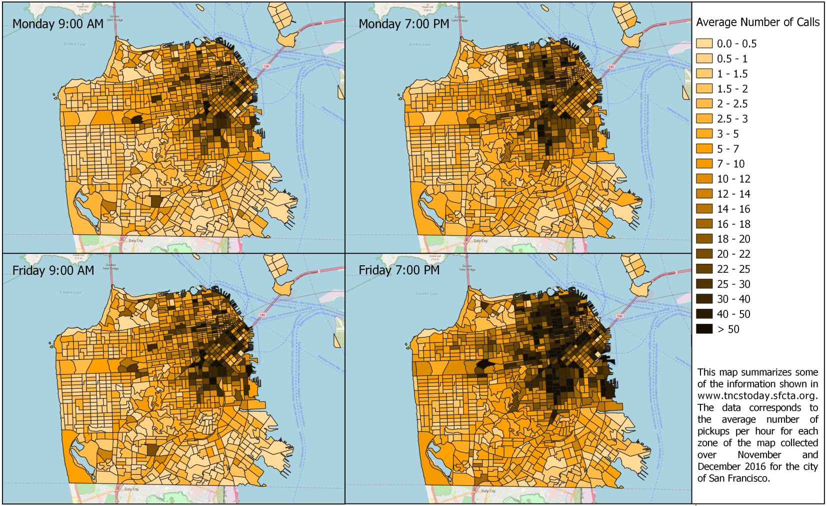
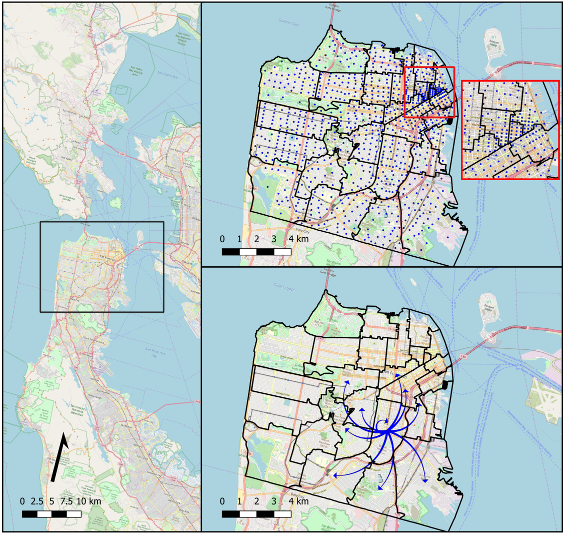
- QGIS for road network.
- 11,372 nodes and 31,428 edges.
- 70x70 meters digital elevation model.
- Speed according to edge classification and adjusted by slope (Verma et al. 2017).
- Shortest path algorithm is based on the network.

Passengers (SFCTA 2017)



This map summarizes some of the information shown in www.tncstoday.sfcta.org. The data corresponds to the average number of pickups per hour for each zone of the map collected over November and December 2016 for the city of San Francisco.

Drivers (Piorkowski et al. 2009)



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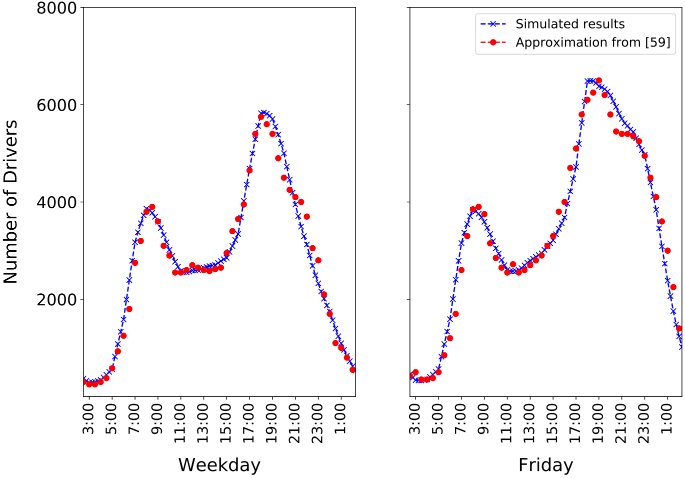
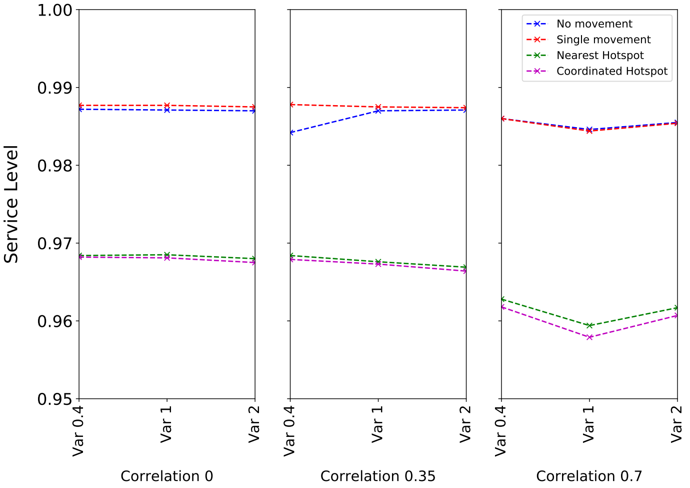
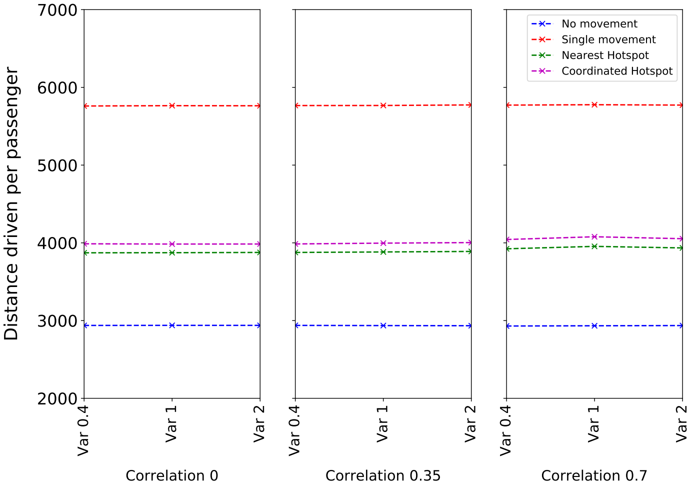


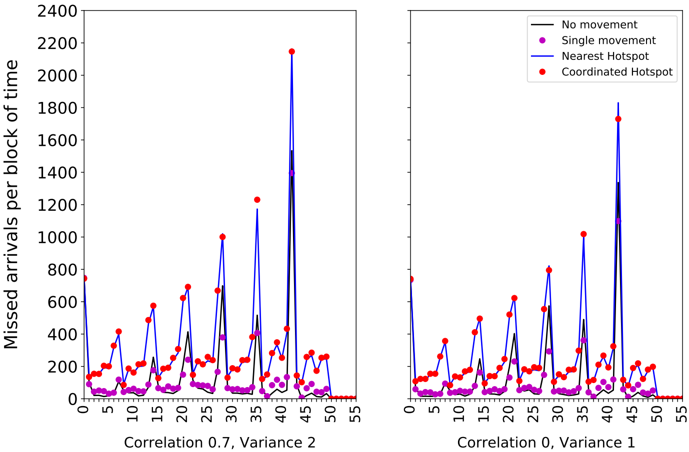
Overall Service Level

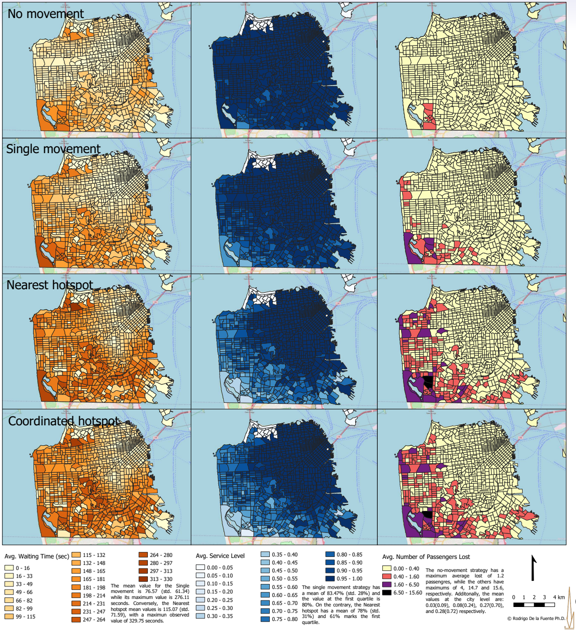


Distance Driven



Chaotic Conditions Effect





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Discussion

- No movement saves at least 11M USD per year and 57M of CO_2 per year in SF versus Single movement.
- No movement is very hard to implement now, needs extensive parking (up to 39,000 sq. meters).
- Nearest Hotspot saves 7.9M USD and 38M of CO_2.
- A need of interaction and mutual agreement between stakeholders. Investments are also needed.
- Spatial discrepancies should be addressed by introducing incentives/new transportation options.

Conclusions and Future Work

- Proposed realistic simulation model that can be used under multiple conditions.
- Framework allows the comparison of different drivers' behaviors while waiting for riders, and also to evaluate the impact in different areas of the city and periods of time.
- Huge benefits can be obtained if the behaviors are optimized.

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- Huge benefits can be obtained if the behaviors are optimized.
- Different matching algorithms $\rightarrow$ dynamic reallocation.
- How to better select the hotspots?
- Pricing incentives and their effects.