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# FDA-VeD: A Future-Demand-Aware Vehicle Dispatching Service

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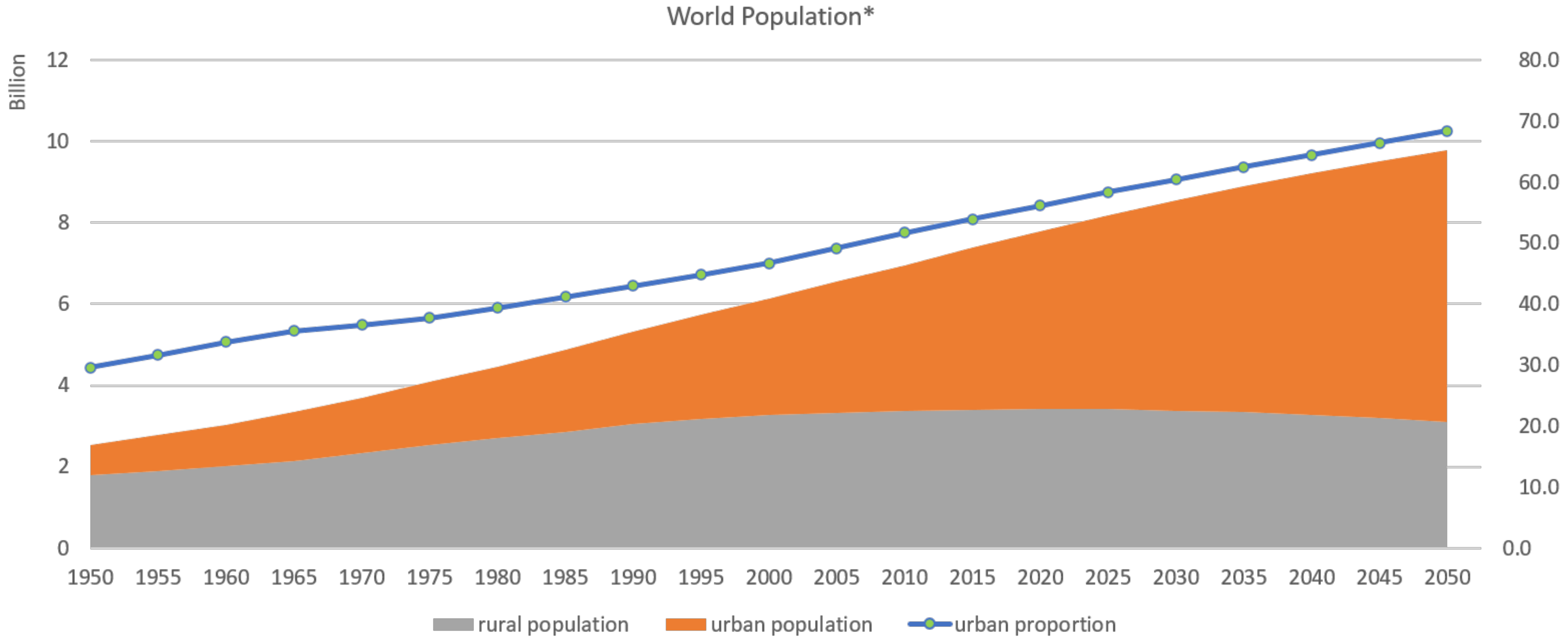
# Background

## FAST GROWING URBAN POPULATION

Fast growing urban population will bring more travel demand and higher pressure for the road and environment.




***: Data from https://population.un.org/wup/Download/**

# Background

## MOBILITY ON DEMAND (MOD)

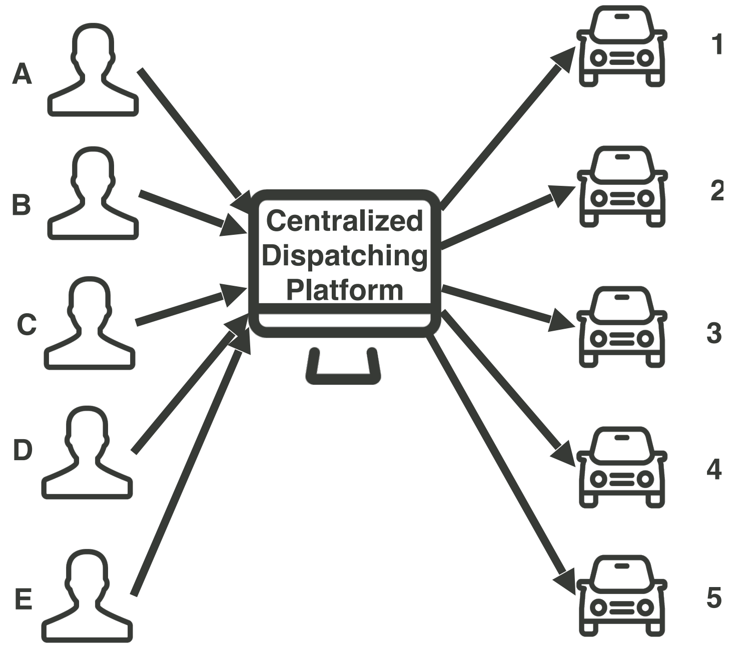
MOD is an innovative, user-focused approach which leverages emerging mobility services, integrated transit networks and operations, real-time data, connected travellers.*

Uber

DiDi

Keoride

Transport on demand.




*: https://www.its.dot.gov/factsheets/pdf/MobilityonDemand.pdf

# Problem

## MAXIMIZE SERVING RATIO

**Objective:**

- Maximize serving ratio ***R***

**Subject to:**

- Number of vehicles **N**
- Road graph **G**
- Real-time trip requests ***T***
- Historical trips ***H***
- Passenger waiting time $\Delta$

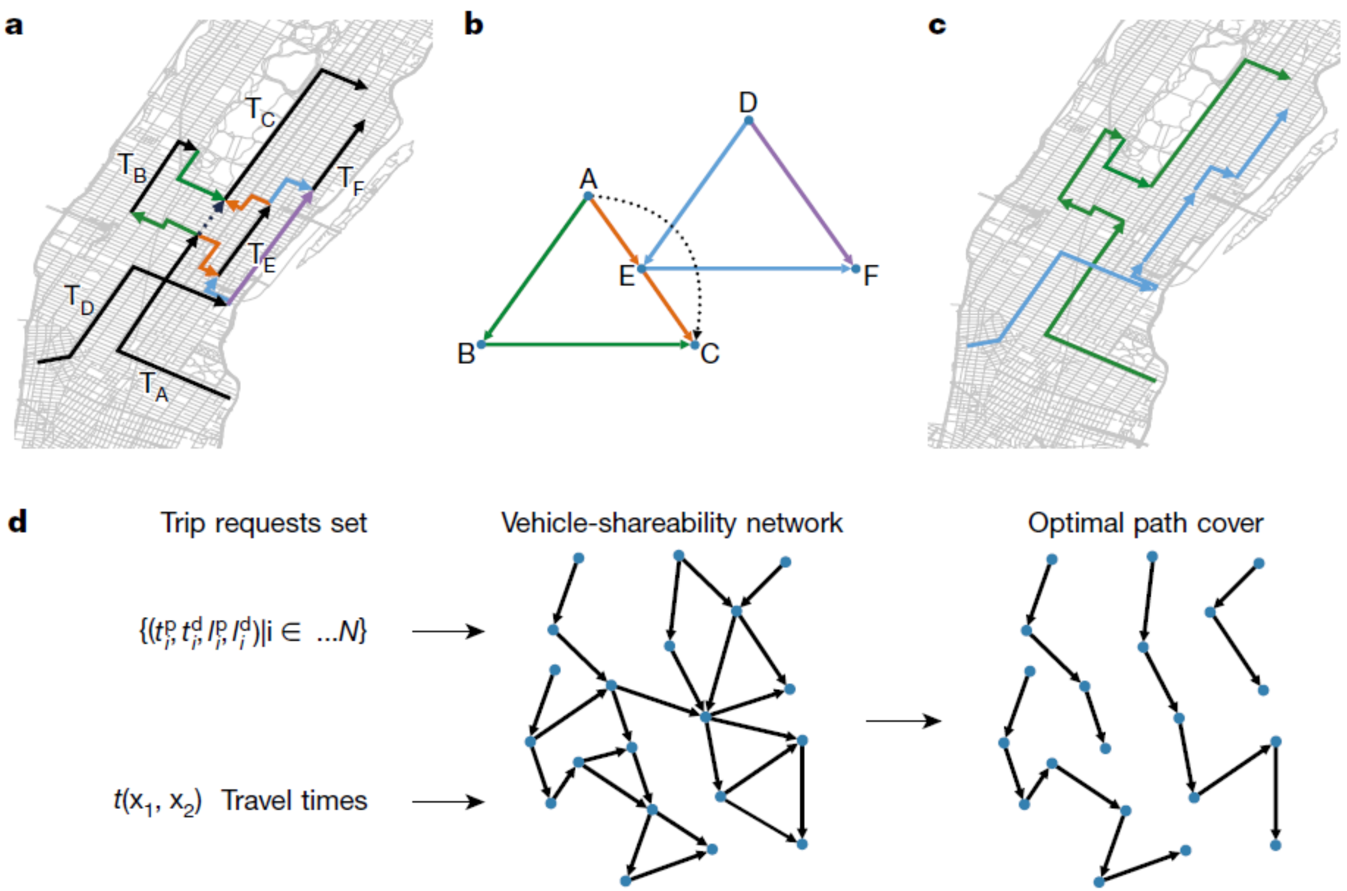
$$\text{maximize} \quad R = \frac{|\mathcal{T}_{served}|}{|\mathcal{T}|},$$

$$\text{subject to} \quad \forall t_i \in \mathcal{T}_{served}, \;\; t_i^p \leq {}^a t_i^p \leq t_i^p + \Delta$$

# Current Works

## DISPATCH FOR REAL-TIME REQUESTS

[M. M. Vazifeh, et al. ***Nature***, 2018] Addressing the minimum fleet problem in on-demand urban mobility




**Static:**

- Optimal solution
- Minimum path cover problem
- Lower bound of vehicles

**Dynamic:**

- Near optimal solution
- Online Batch model

# Current Works

## CONSIDER POTENTIAL FUTURE DEMANDS

[M. Chen, et al. ***WWW***, 2018] Optimal Vehicle Dispatching for Ride-sharing Platforms via Dynamic Pricing

[H. Ma, et al. ***ACM EC***, 2019] Spatio-Temporal Pricing for Ride-sharing Platforms

- **Use dynamic price to rebalance the supply and demand between areas**

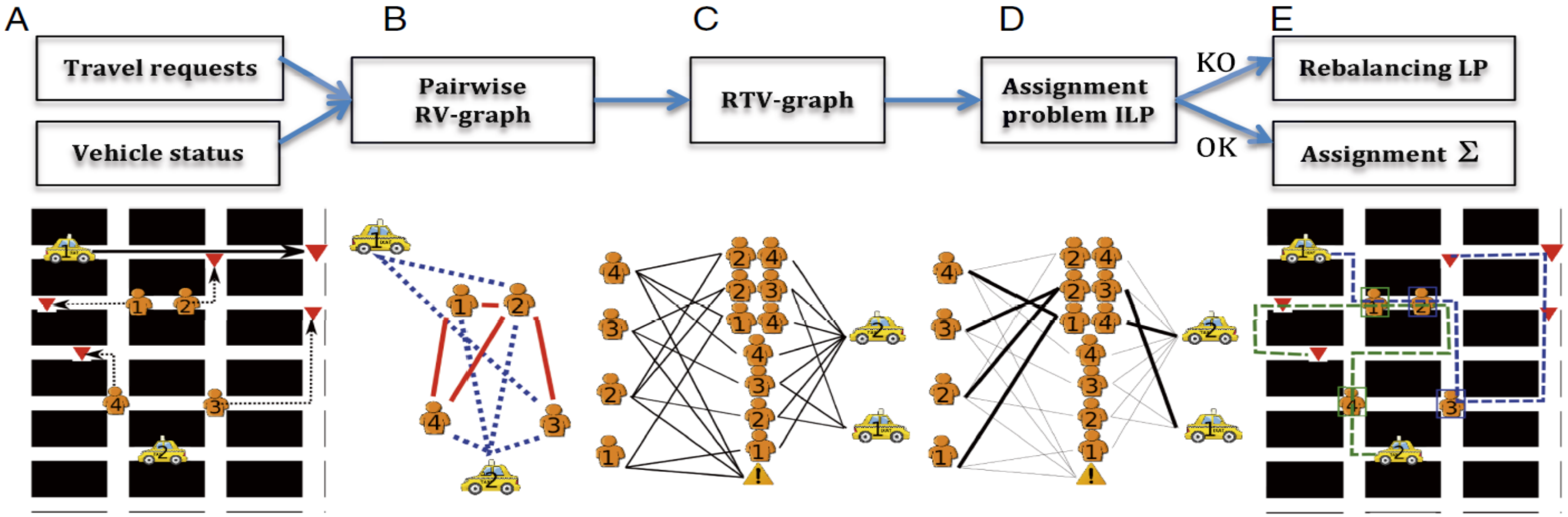
The high price may suppress the demand not serve the demands.
Improve serving ratio by less demands.

# Current Works

## CONSIDER POTENTIAL FUTURE DEMANDS

[J. Alonso-Mora, et al. ***PNAS***, 2018] On-demand high-capacity ride-sharing via dynamic trip-vehicle assignment

[A. Wallar, et al. ***IROS***, 2018] Vehicle Rebalancing for Mobility-on-Demand Systems with Ride-Sharing

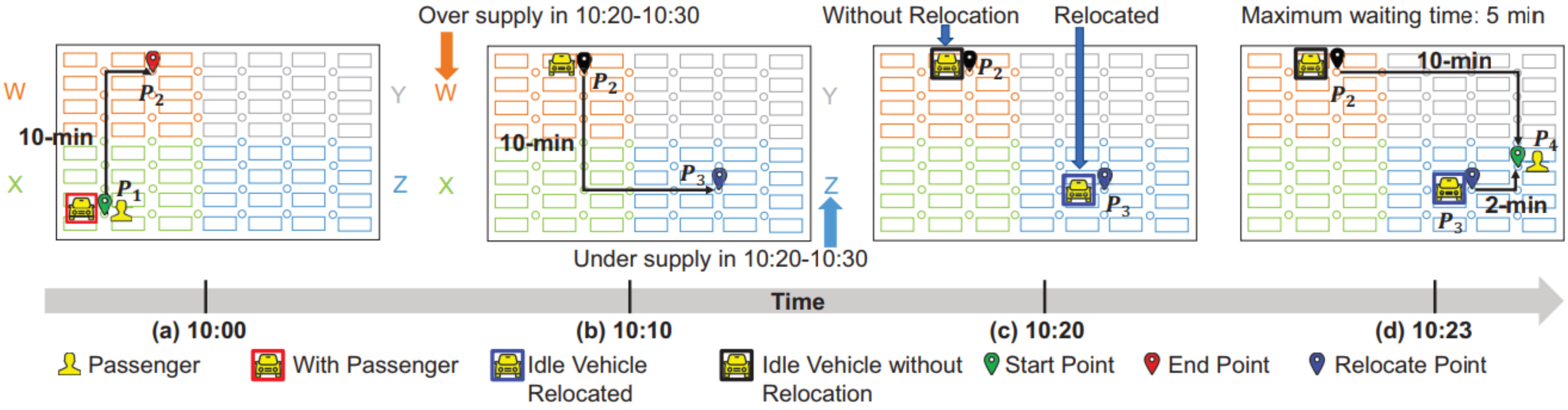



- Only consider pickup demands
- High relocation frequency (30s) and high operate cost improvement

# Method

## HIGH LEVEL IDEA

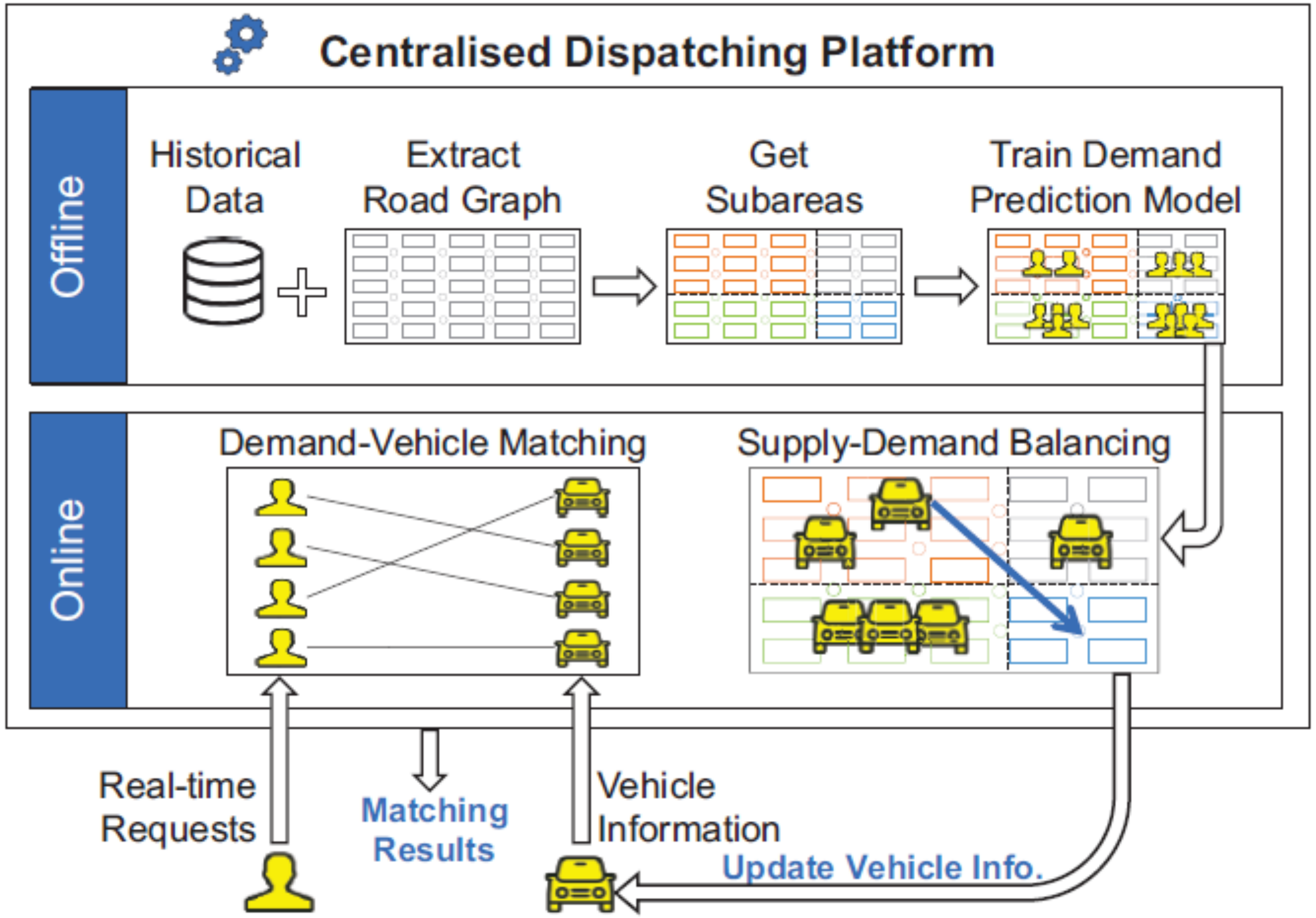
Relocate idle vehicles to undersupply areas to serve the potential future demands



# Method

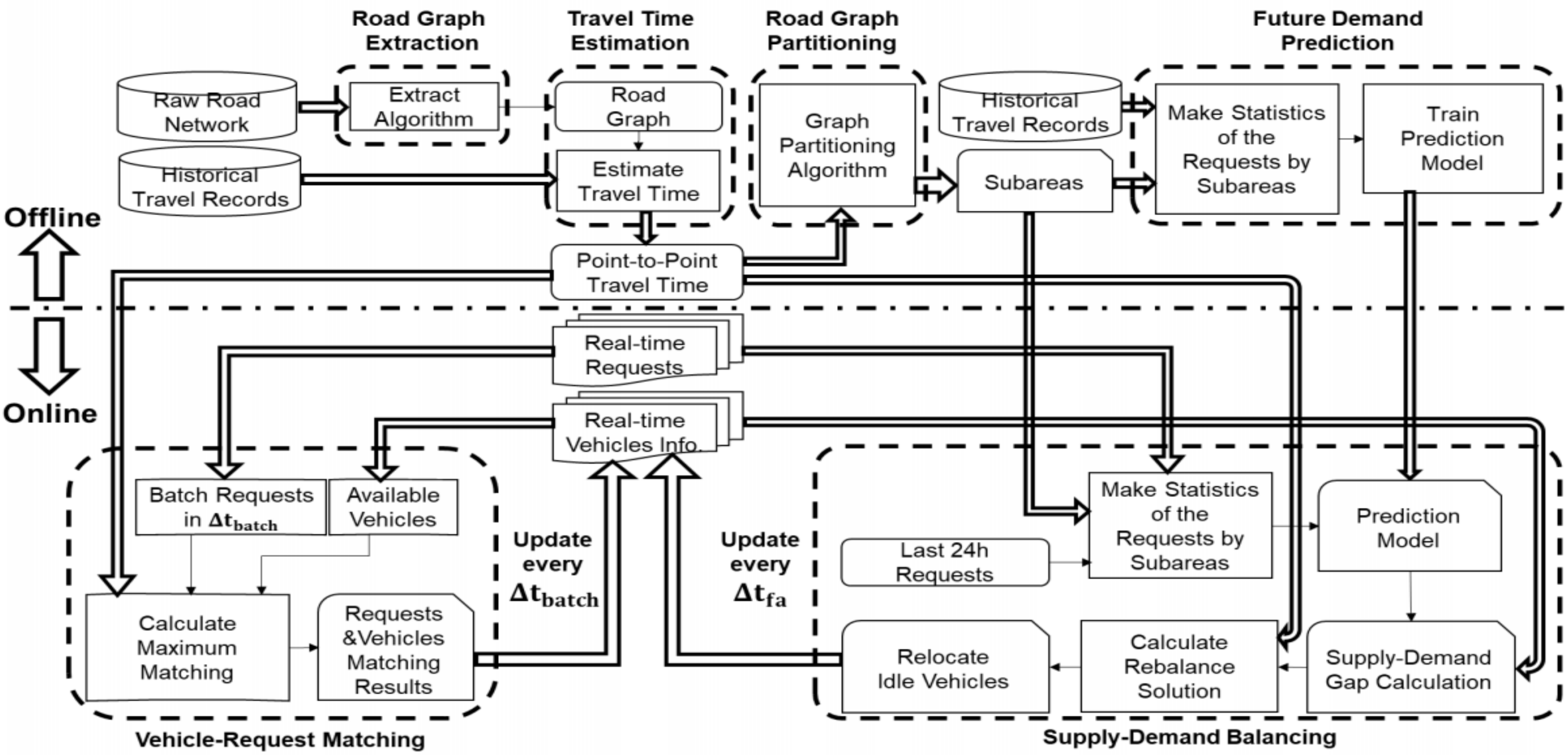
## FRAMEWORK

FDA-VeD service is designed for centralised dispatching platform. It considered future demand to relocate the idle vehicles and improved the serving ratio with small operation cost.



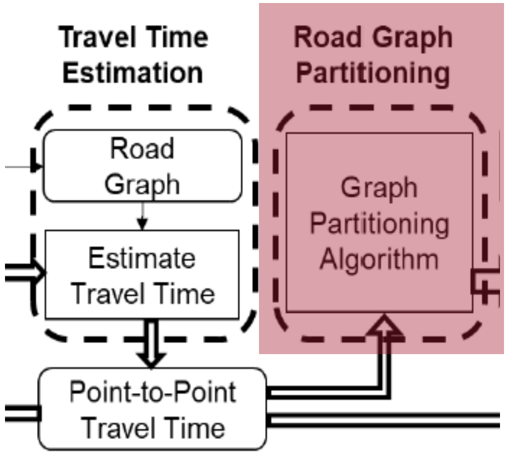
# Method

## FRAMEWORK



# Method

## OFFLINE - ROAD GRAPH PARTITIONING




**III. Divide subarea**

$$eet'_{i,j} = \begin{cases} 1 & \text{if } eet_{i,j,h'} \leqslant \Delta \\ 0 & \text{if } eet_{i,j,h'} > \Delta \end{cases}$$

$i_{sub} = 1;$

**while** $i_{sub} \leqslant n_{sub}$ **do**

- $i_c = \arg\max_i \Sigma_{j=1}^{n_{point}} eet'_{i,j}$
- $n_r = \Sigma_{j=1}^{n_{point}} eet'_{i_c,j}$
- $A' = \{j | eet_{h',i_c,j} \leqslant \Delta\}$
- **if** $n_r \leqslant n_{max}$ **then**
  - $A_{i_{sub}} = A'$
- **else**
  - $A_{i_{sub}} = \text{top}(A', i_c, n_{max})$
- $\forall i \in A_{i_{sub}}, \quad eet'_{i,j} = 0$
- $\forall j \in A_{i_{sub}}, \quad eet'_{i,j} = 0$
- $i_{sub} = i_{sub} + 1$

$P' = \{i | \Sigma_{j=1}^{n_{point}} ett'_{i,j} > 0\}$

**for** $p \in P'$ **do**

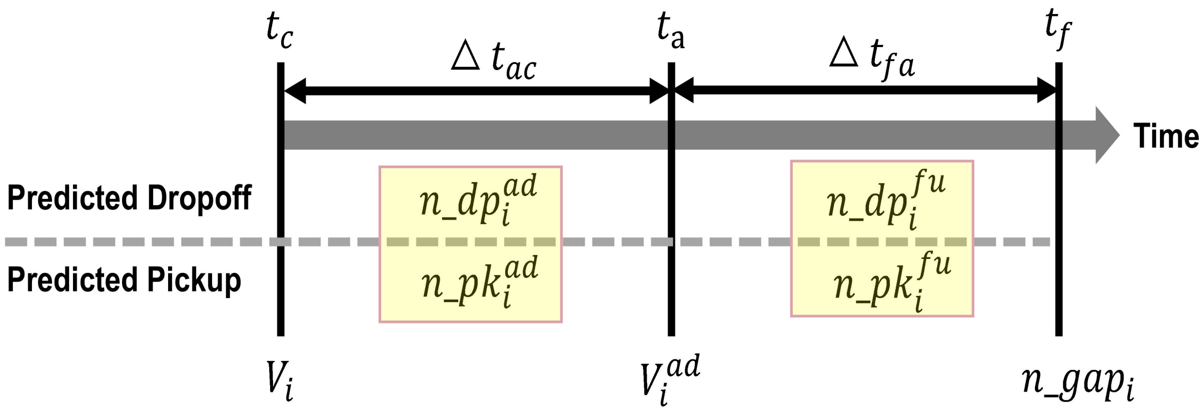
- match $p$ to $A_i$ whose central point could reach $p$ in shortest time

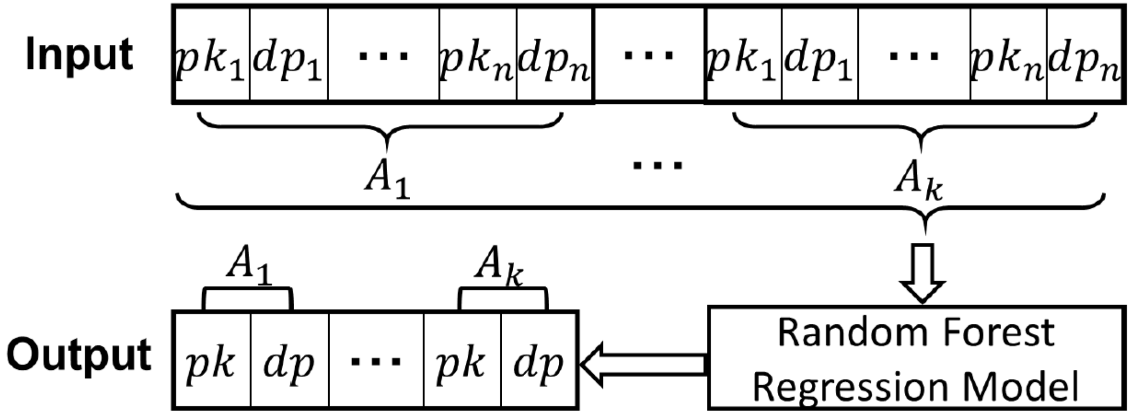
**Road graph partition**:

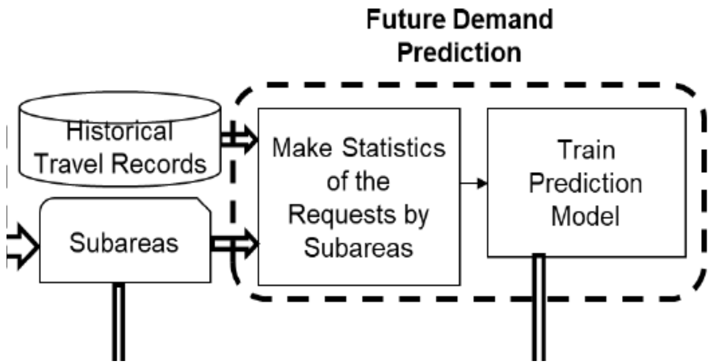
- Partition graph based on given size and maximum waiting time.
- The partitioning solution can be solved in $\mathcal{O}(n_{sub}|A|^2)$
- Has the potential to run in online partitioning scenario

# Method

## OFFLINE - FUTURE DEMAND PREDICTION



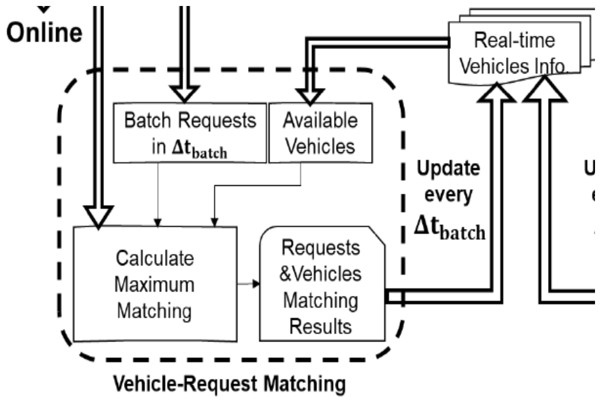



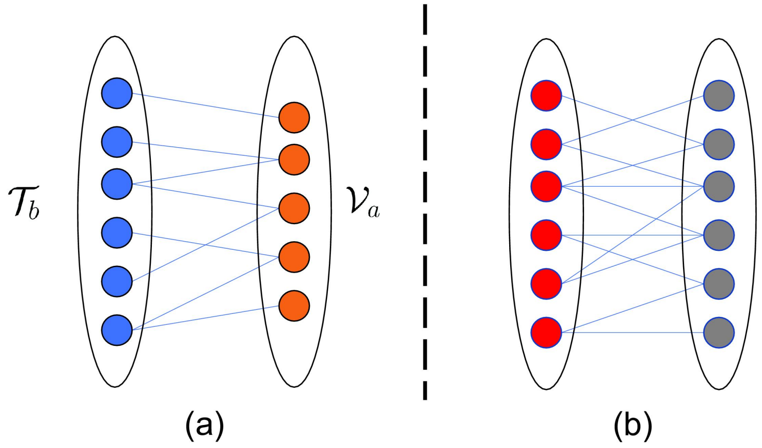



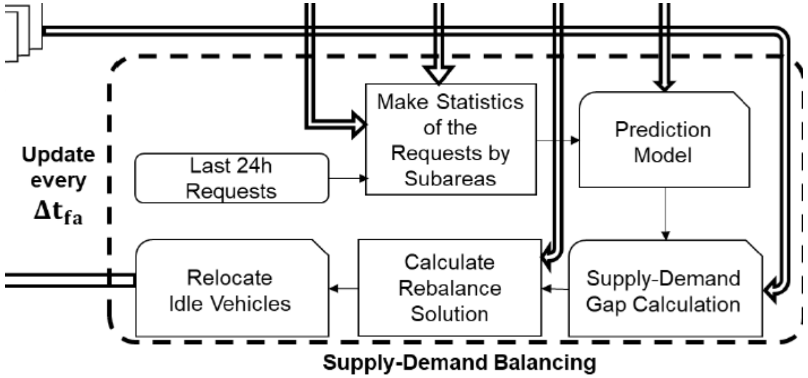

**Future demand prediction**: Predict potential future pickup and drop off demands in two time-intervals (advance interval & future interval)

# Method

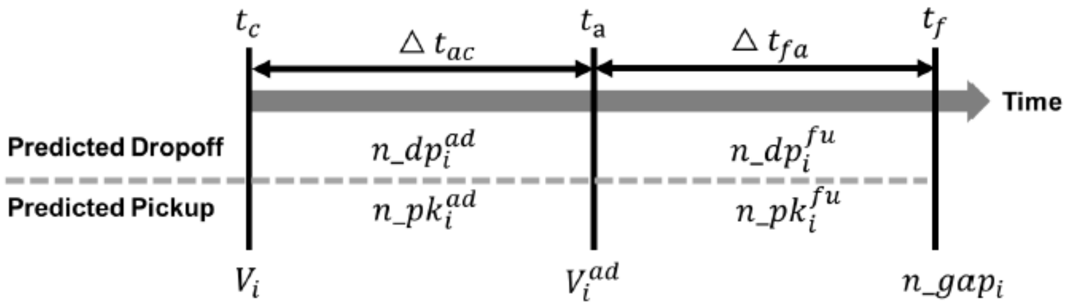
## ONLINE – MATCHING AND REBALANCING




- Centrals in undersupply subareas
- Idle Vehicles




$$n\_V_i^{ad} = n\_V_i + n\_dp_i^a - n\_pk_i^a$$

$$n\_gap_i' = n\_dp_i^f - n\_pk_i^f$$

$$n\_gap_i = max(V_i^{ad}, 0) + min(n\_gap_i', 0)$$

# Experiments

## DATASET AND SETUP

**Dataset:**

**Trip records dataset** The trip records in New York City at January 2011

**Road network** for Manhattan Island from www.openstreetmap.org.

**Setup:**

**Passengers' maximum waiting time:** 5 minutes

**Number of Vehicles**: 2,000 to 10,000 by step 1,000

**Advanced time slot** $\Delta t_{ac} = 10, 20, 30$

**Future time slot** $\Delta t_{fa} = 10$

**Batch time** $\Delta t_{batch} = 1$

# Experiments

## EVALUATION METRICS

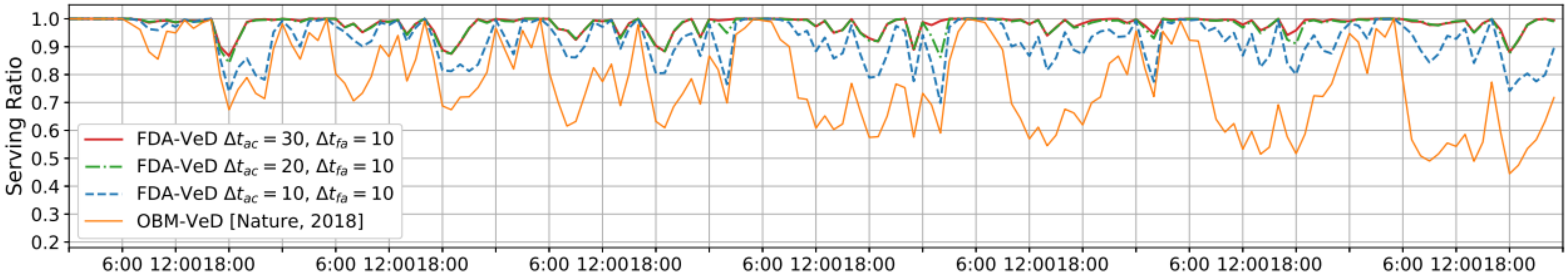
**Passenger serving ratio R:** served trips against total trips

**With-passenger ratio** $r_1$: with-passenger travel length vs total drive length

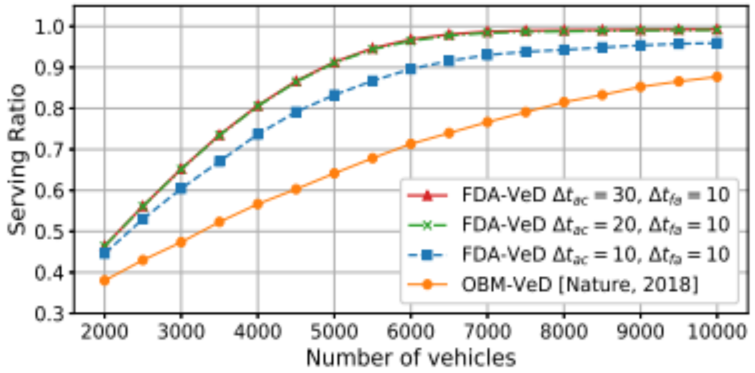
**Gain–cost ratio** $\boldsymbol{r_{gc}}$ : relocation travel length vs increased with-passenger length

# Experiments

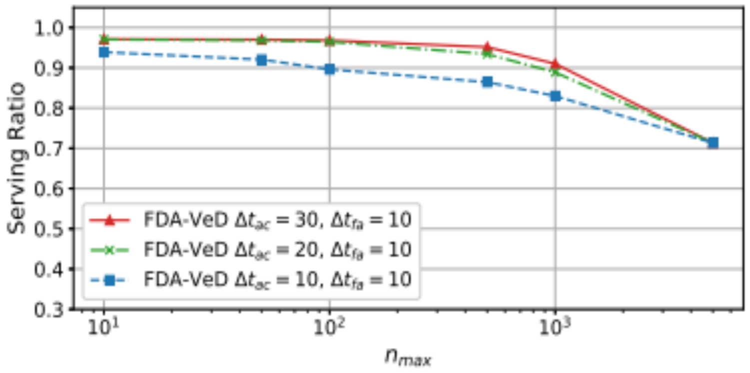
## RESULTS




Passenger serving ratio and Number of requests by hour in Manhattan Island (20110112-20110118)




(a) $R$ against different number of vehicles




(b) $R$ against different size of subarea

OPERATING COST

| Item | OBM-VeD | FDA-VeD $\Delta t_{fa} = 10$ | | |
|---|---|---|---|---|
| | | $\Delta t_{ac} = 10$ | $\Delta t_{ac} = 20$ | $\Delta t_{ac} = 30$ |
| $d_1$ | 145.8 | 185.7 | 203.4 | 204.4 |
| $d_2$ | 44.9 | 54.5 | 58.0 | 58.3 |
| $d_3$ | 0 | 6.0 | 19.7 | 24.9 |
| $d_{all}$ | 190.7 | 246.2 | 281.1 | 287.6 |
| $r_1$ | 0.76 | 0.75 | 0.72 | 0.71 |
| $d_g$ | - | 39.9 | 57.6 | 58.6 |
| $d_c$ | 0 | 6.0 | 19.7 | 24.9 |
| $r_{gc}$ | - | 6.64 | 2.93 | 2.36 |

# Conclusion & Future Work

Conclusion:

- By considering both the pickup and drop-off demand for each area, we could relocate idle vehicles for a long future time interval
- With proper advance relocation time slot, a significant improvement in serving ration] could be achieved with really low cost

Future Work:

- Consider more factors (e.g. traffic, demands, vehicles and so on) to partition the road graph in online fashion
- Consider the economic effect for the dispatching platform

# Q&A