Smart Mobility:
Optimization and Behavioral Modeling

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Smart Mobility: Introduction

- Mobile technology
- Real-time / on-demand
- Personalized
- Shared

Smart Mobility: Mobile Technology

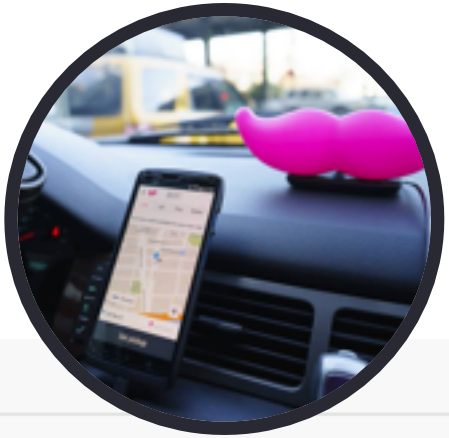
Autonomous

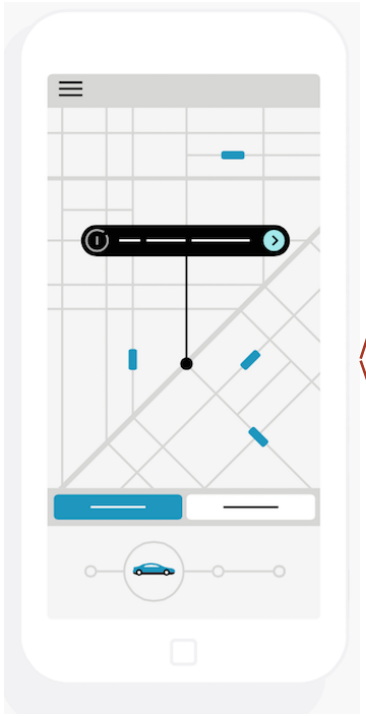
App-based

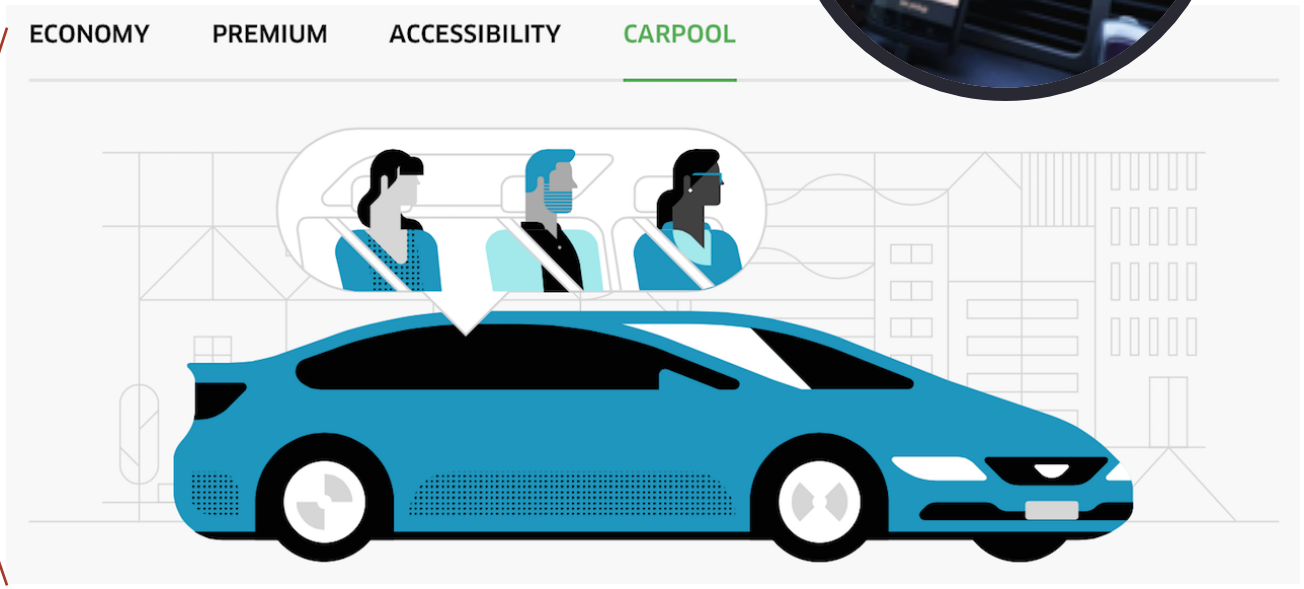
Connectivity

Smart Mobility: On-Demand

Uber, Lyft…



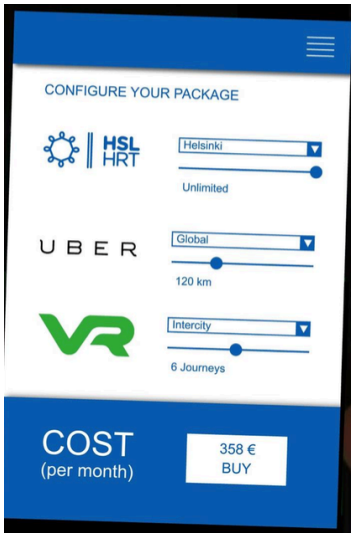




Smart Mobility: Personalized

Flexible Mobility On-Demand (FMOD)

Mobility as a Service (MaaS)



Smart Mobility: Shared

Car sharing, carpooling lanes, ride sharing, bike sharing….

By The New Yorker, MAY 16, 2016

"Hang on—I'll Uber us a school bus."

Research Agenda

Behavioral Data

Behavioral Models/Optimization

Solutions

Designing Effective Smart Mobility Solutions

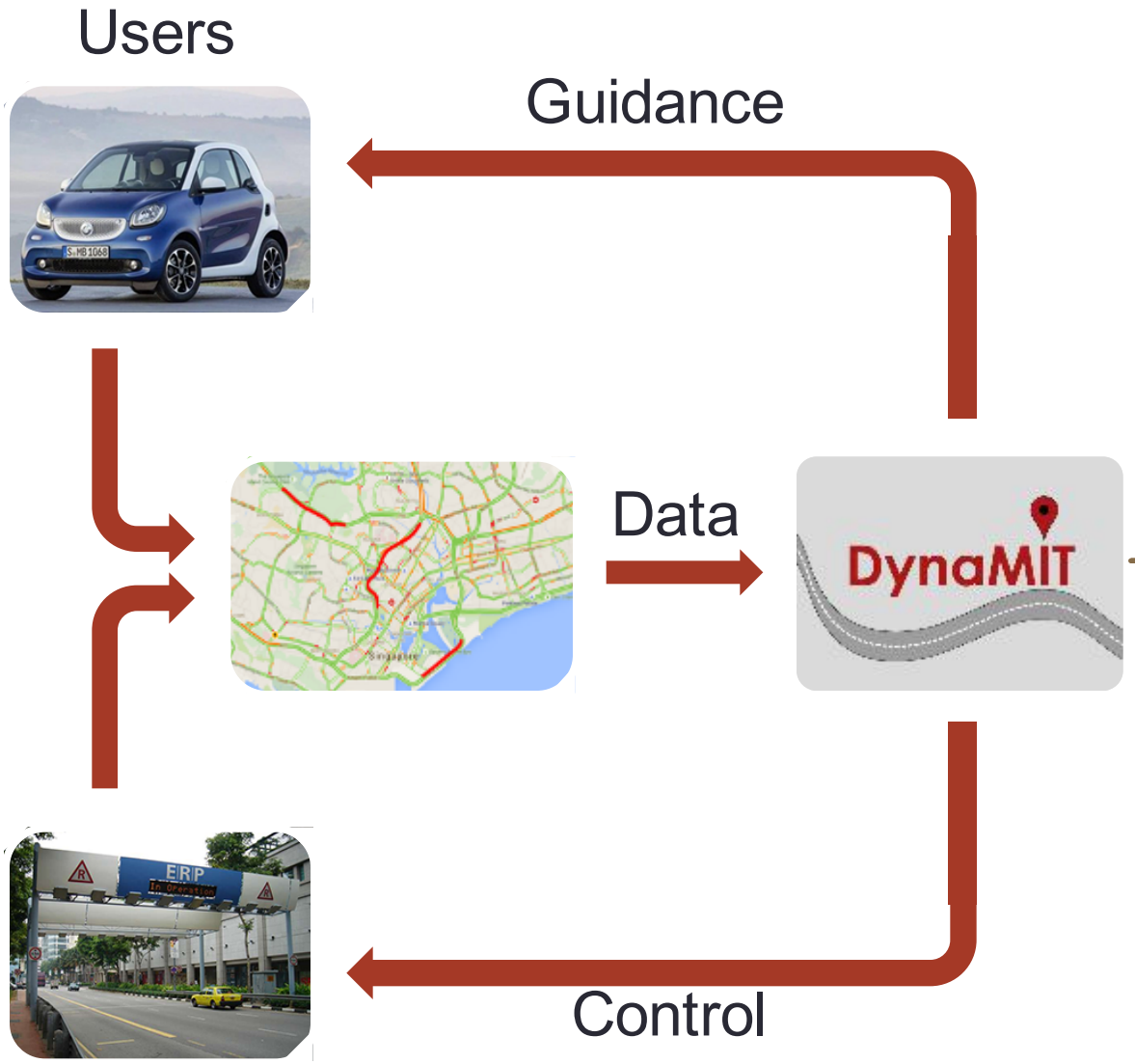
- **Efficiency** → **optimization**
- **Personalization** → **behavioral modeling**
- **Real-time** → **app-based platform (FMS)**
  http://its.mit.edu/future-mobility-sensing
- **Testing** → **SimMobility**
  http://its.mit.edu/research/simmobility

Research Projects: Solutions

- Real-time Toll Optimization based on Prediction
- Flexible Mobility on Demand (FMOD)
- Autonomous Mobility on Demand (AMOD)
- Mobility Electronic Market for Optimized Travel (MeMOT)

Real-time Toll Optimization based on Prediction

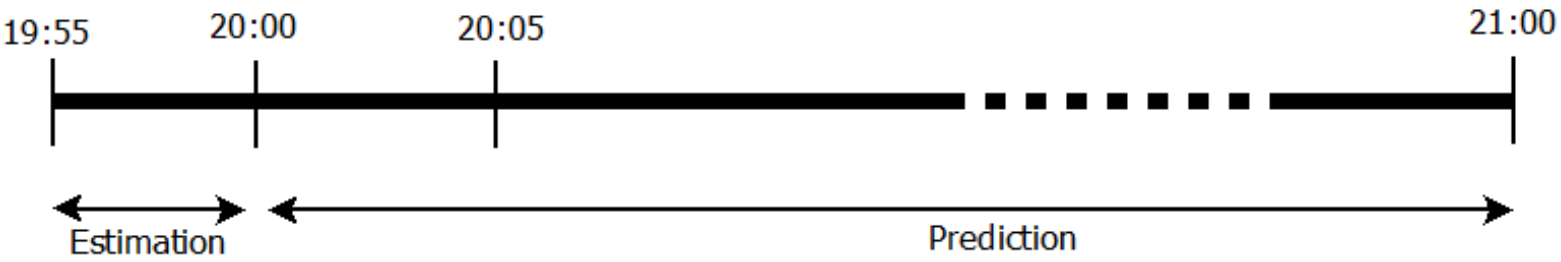
Real-time Toll Optimization based on Prediction



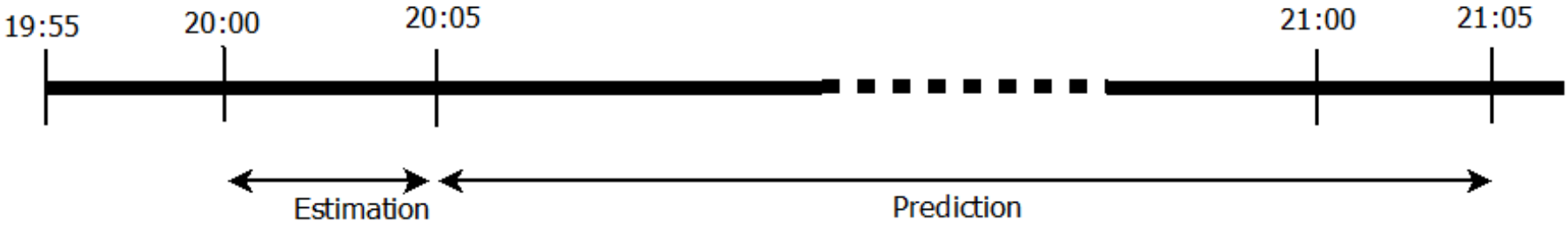
- Data fusion
- Incidents
- Self-calibration
- **Behavioral models** (e.g., route choice, departure time choice)
- Prediction
- **Optimization**

Rolling Horizon

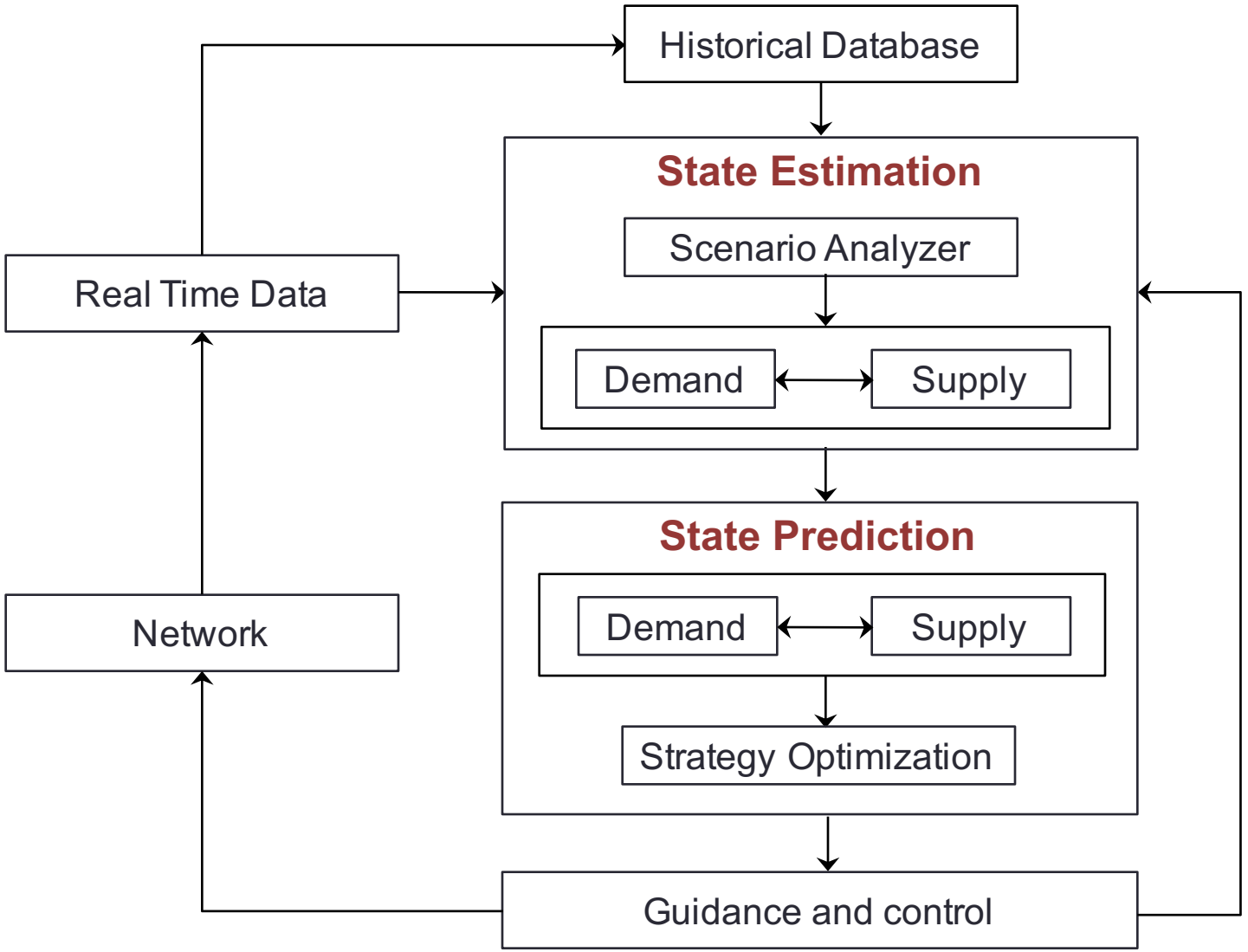
Time = 20:00. Execution Cycle 1 begins



Time = 20:05. Execution Cycle 2 begins



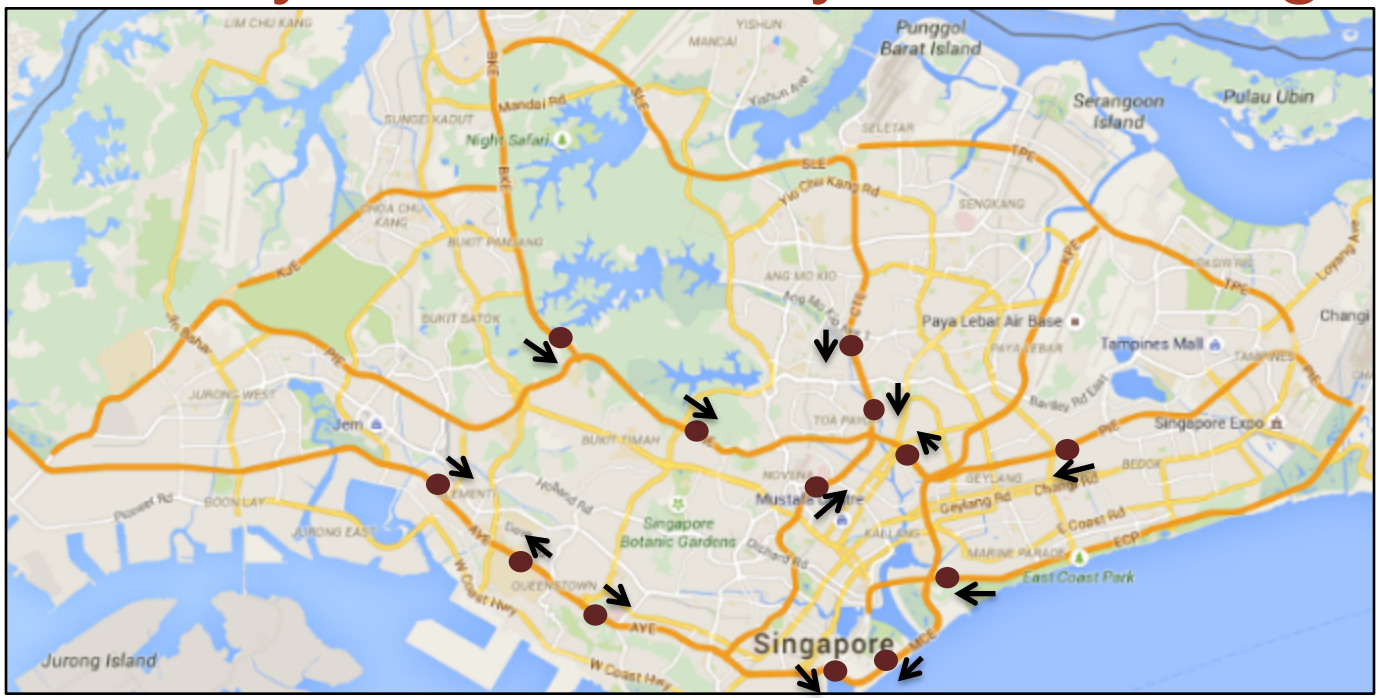
DynaMIT 2.0: System Architecture



Case studies

- Area-wide tolling in Singapore
- Managed lanes in Texas

Case Study: Area-wide dynamic tolling

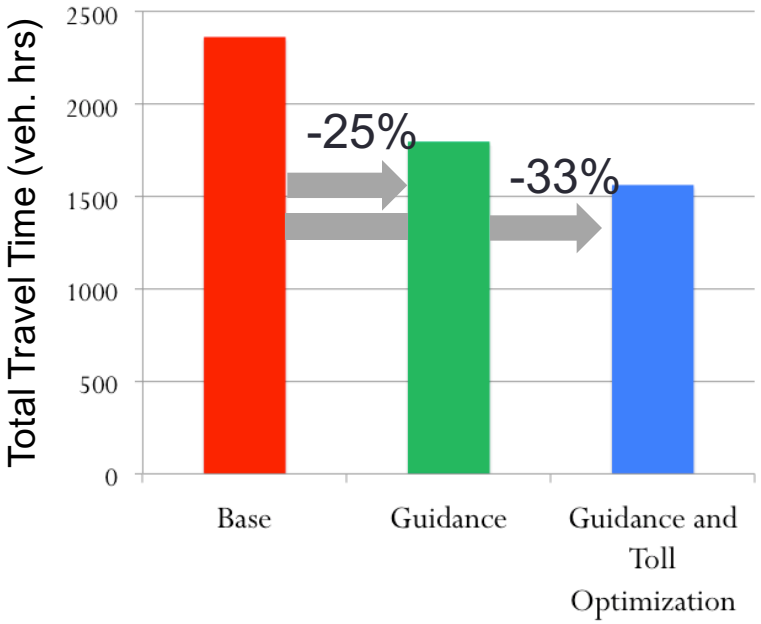


- Minimize total travel time in the network (fixed total demand)
- Historical dataset on incidents/road works (Sept. 15th, 2011)
- Simulation period: 7:30 AM ~ 2:30 PM
- 13 toll gantries
  - Toll rates changing at 5 min interval

Three Scenarios

Base case	No guidance
Guidance	Predictive guidance with DynaMIT
Guidance and toll optimization	DynaMIT guidance and optimized tolls

Reduction in Network Delay



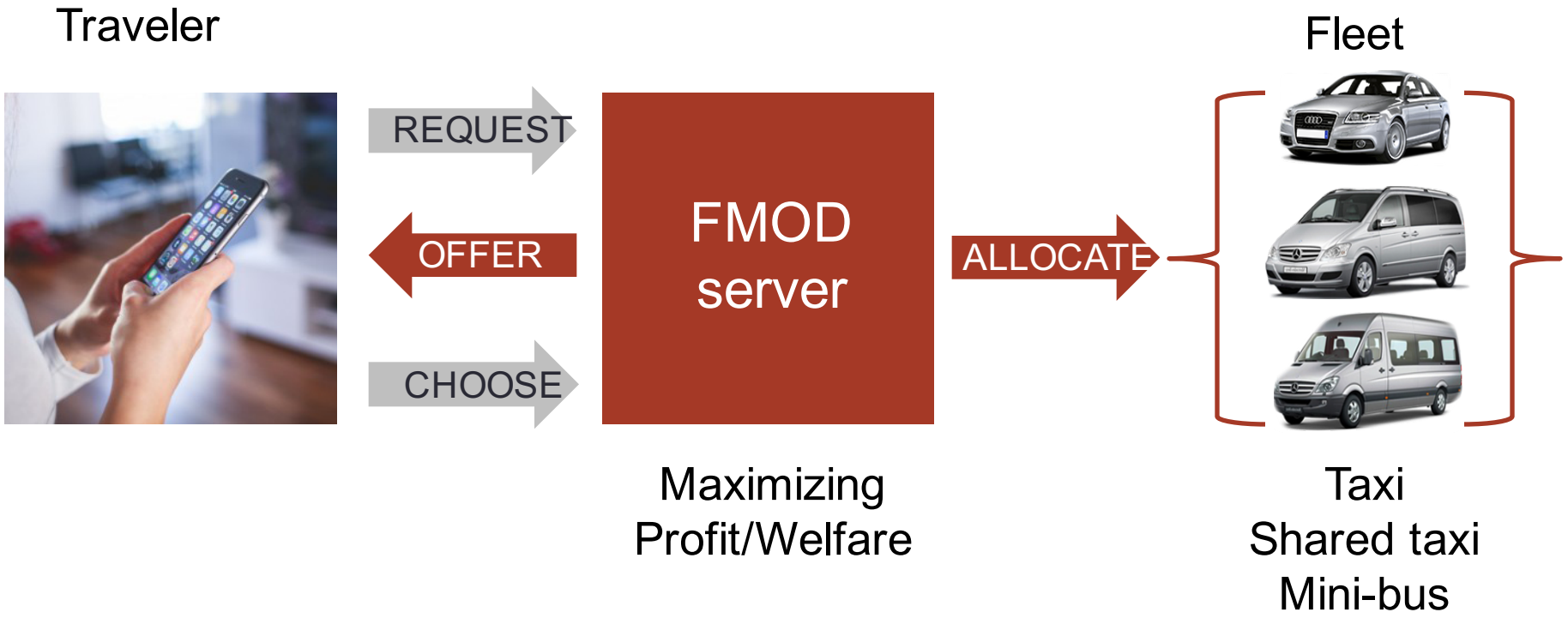
Scenario	Travel Time of affected* drivers (veh. hrs)	Total Travel Time (veh. hrs)
Base	2,184	87,645
Guidance	1,648 (-25%)	81,626 (-7%)
Guidance & toll optimization	1,473 (-33%)	79,141 (-10%)

**Affected vehicles are defined as vehicles passing incident locations*

Flexible Mobility on Demand (FMOD)

Flexible Mobility on Demand (FMOD)

FMOD provides a **personalized** and **optimized** menu of travel options in **real-time.**



Dynamic allocation of vehicles to services

FMOD Services

Flexibility to choose from different levels of services

- **Taxi:** door-to-door, private

- **Shared-taxi:** door-to-door, shared

- **Mini-bus:** fixed stops, shared

FMOD User Experience

Traveler

Request:
Origin: A, Destination: B
Preferred Departure Time: 8:00 – 8:30
/ Preferred Arrival Time: 8:45 – 9:00

REQUEST

OFFER

Offer:

taxi:	DT: 8:25/AT: 8:45, $20
shared-taxi:	DT: 8:27/AT: 8:57, $10 as the 4th passenger
mini-bus:	DT: 8:14/AT: 8:59, $5 as the 6th passenger

CHOOSE

Choice:
service: shared-taxi
DT: 8:27/AT: 8:57, $10

Supply Demand

FMOD Server

Optimization and Preferences

Maximizing profit/welfare

Menu optimization

Phase1. Feasible product set generation

- Existing commitments
- Capacity constraints
- Scheduling constraints

Phase 2. Assortment optimization

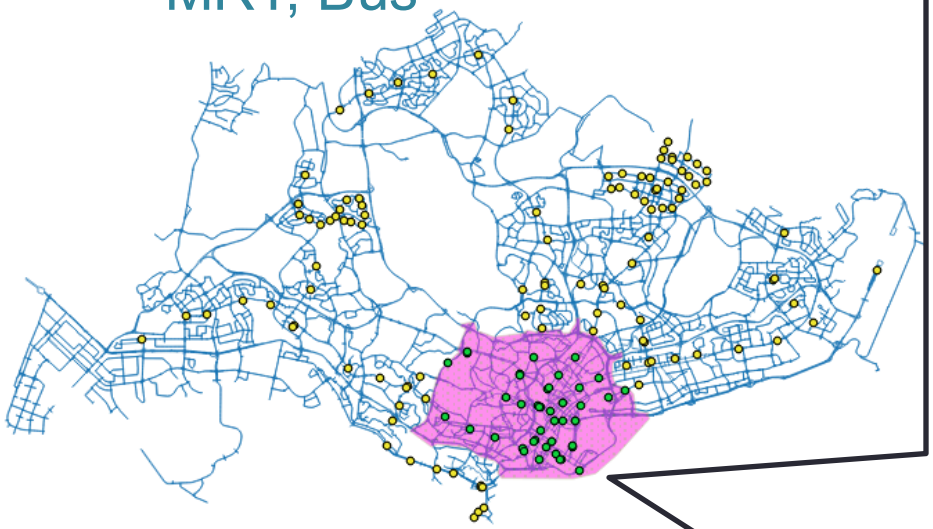
Menu offered to the traveler from the feasible set

- Maximize profit/welfare based on a **behavioral model** (mode choice)

Simulation Experiments in Singapore

1. Base Case

Taxi, Private vehicle, MRT, Bus



2. Scenario with FMOD

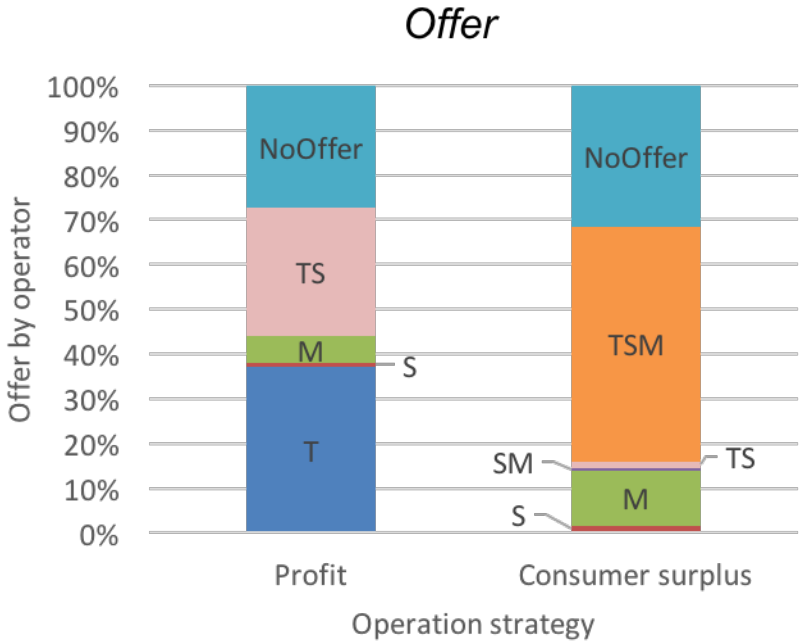
Taxi, Private vehicle, MRT, Bus, **FMOD**

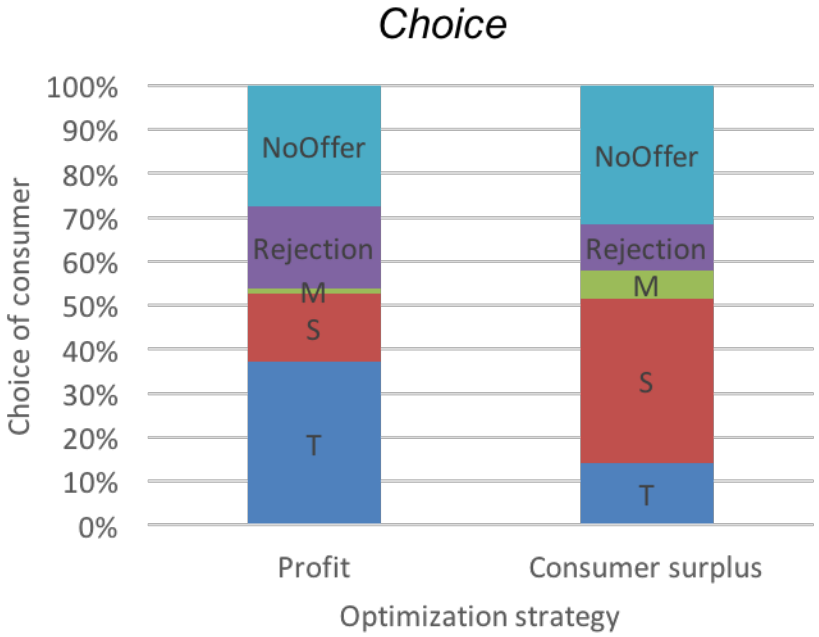
Extended CBD area

- Network configuration:
  - 2706 links - 1294 intersections
  - More than 2000 loop sensors
  - 46 MRT stations
- Simulation setting
  - 6:00 – 7:00 AM
  - Calibrated demand (08/2013)
  - 10% of all road users have access to FMOD
  - 500 FMOD vehicles

Results: Offer and Choice

T: taxi, S: shared-taxi, M: minibus

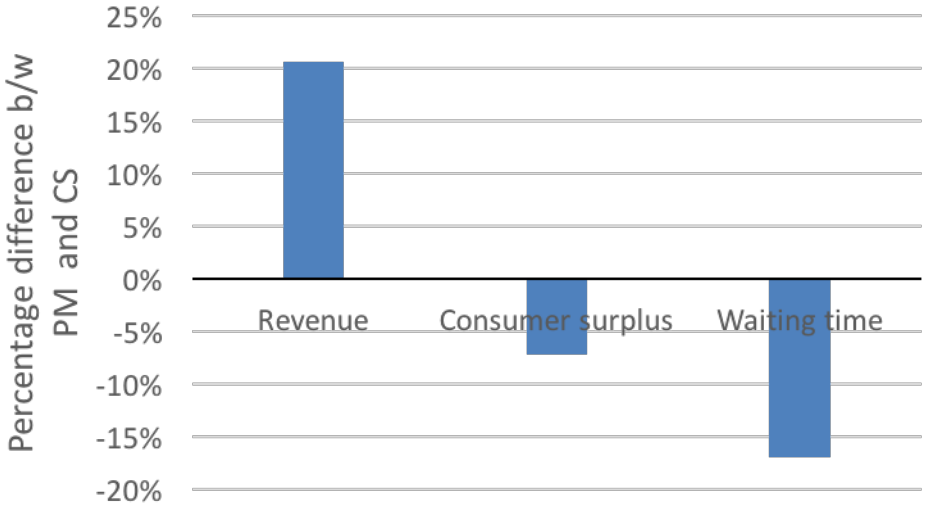




- Large share of taxis with ‘Profit maximization’
- Large share of shared-taxi with ‘Consumer surplus’
- Lower reject rate with ‘Consumer surplus’

Results: Operator and User Benefit

Comparison of different strategies (PM and CS)

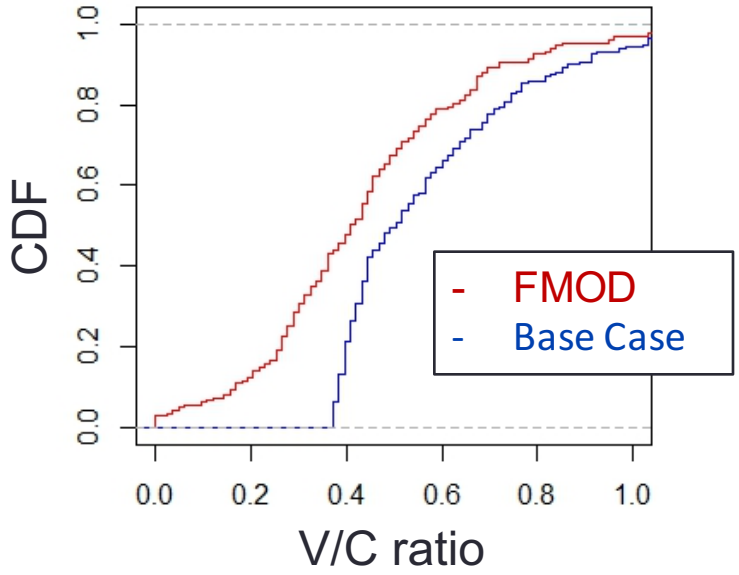


*Percentage difference=(PM - CS) / PM *100*

- 'Profit Maximization' (PM)
  - More revenue for the operator
  - Less waiting time for the user
- 'Consumer Surplus Maximization' (CS)
  - More consumer surplus

Results: Network Performance

Comparison of FMOD (Max. 'Consumer surplus') and Base Case with same demand

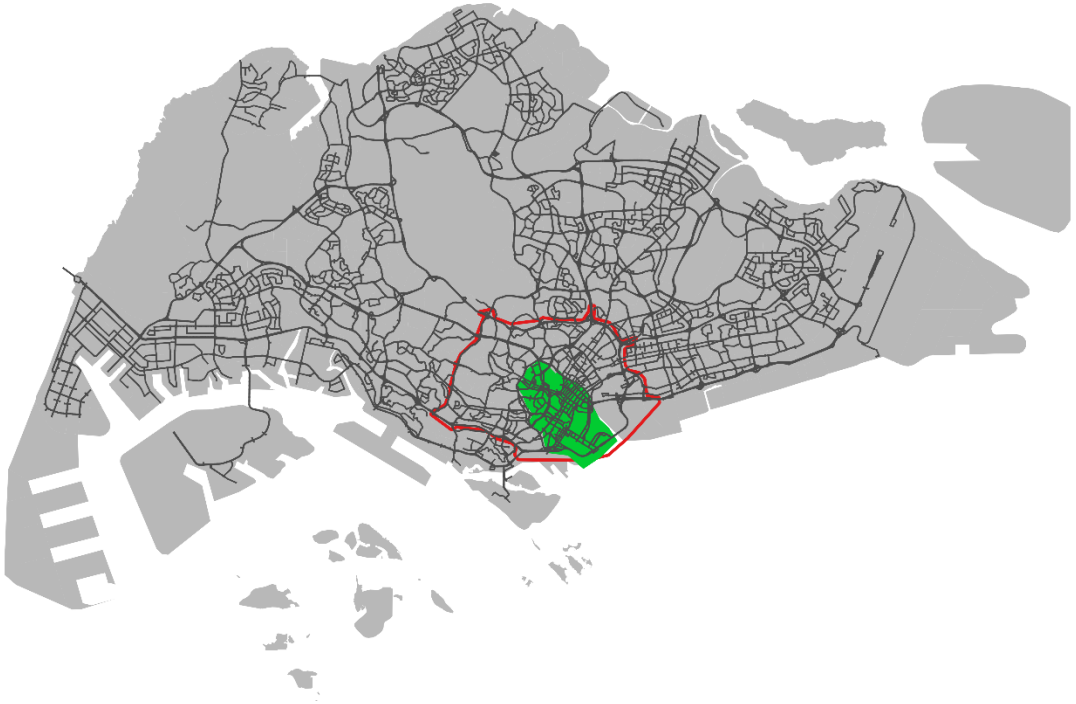


- Significantly lower V/C ratio in FMOD w/o increasing travel-time
  - 10~20% decrease in average V/C ratio
  - Similar travel-time (avg. difference < 10sec)

Autonomous Mobility on Demand (AMOD)

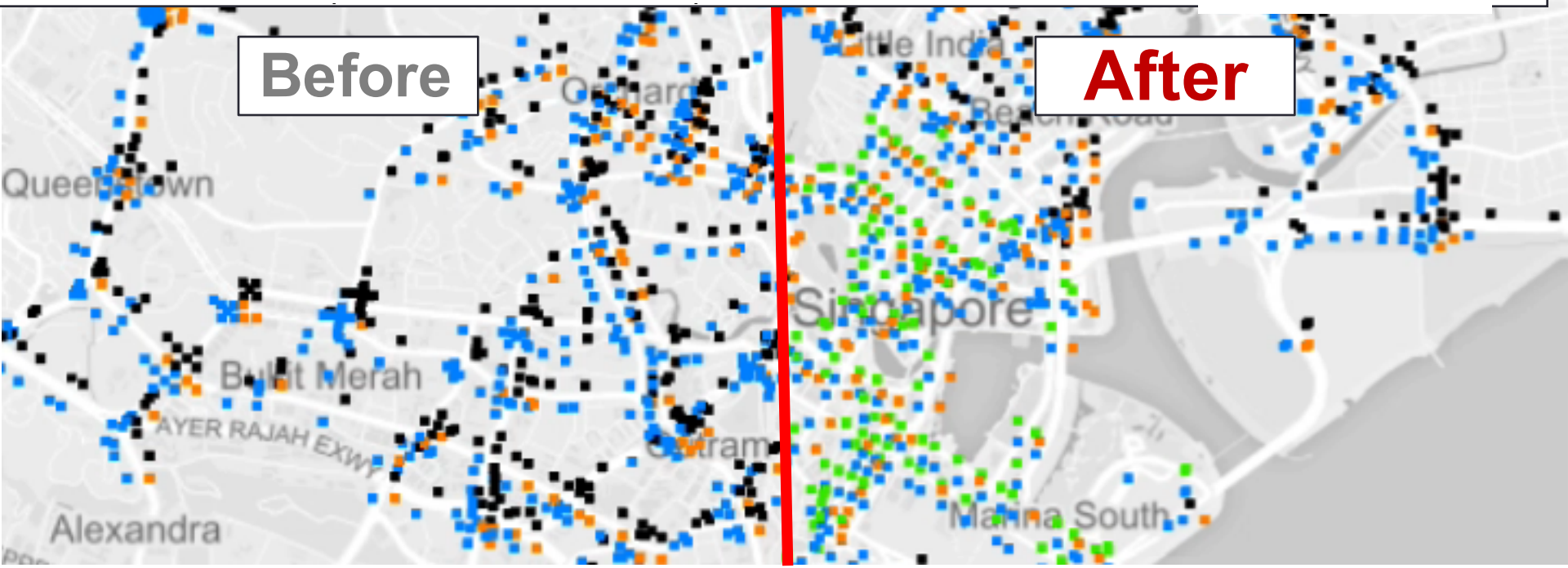
Autonomous Mobility on Demand (AMOD)

● Bus ● MRT ● Taxi ● Private vehicles

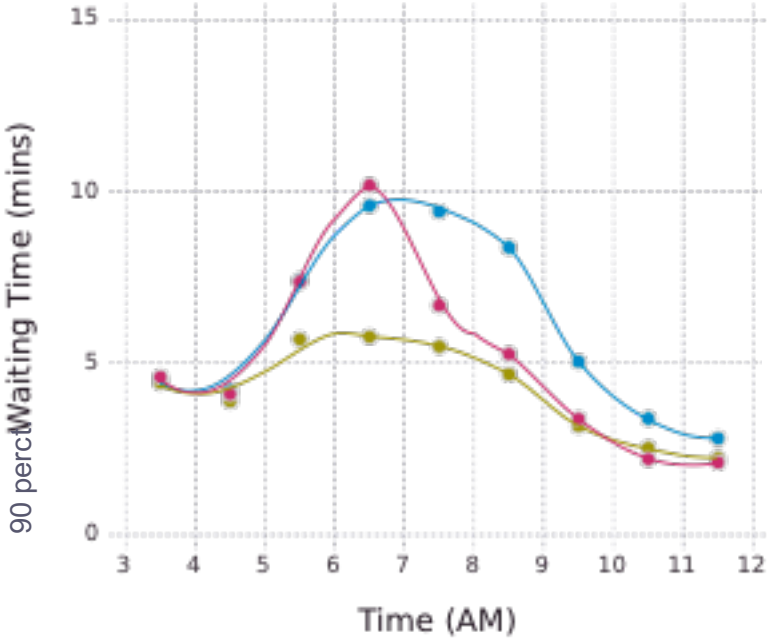


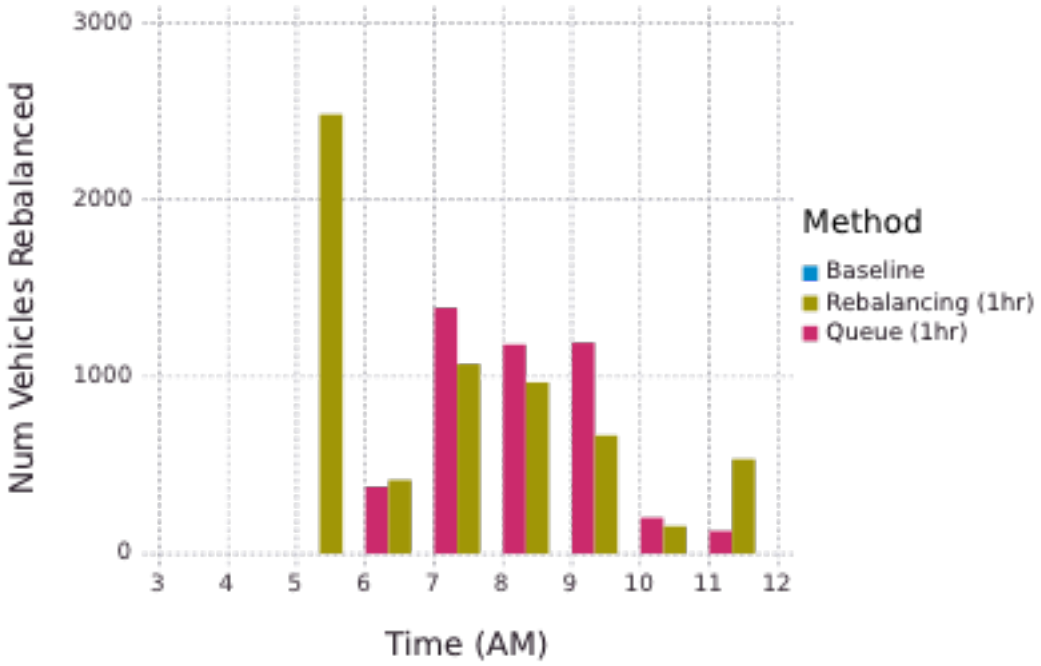
● Bus ● MRT ● Taxi ● ~~Private Vehicles~~ ● **Autonomous MOD**

Results: User Choices

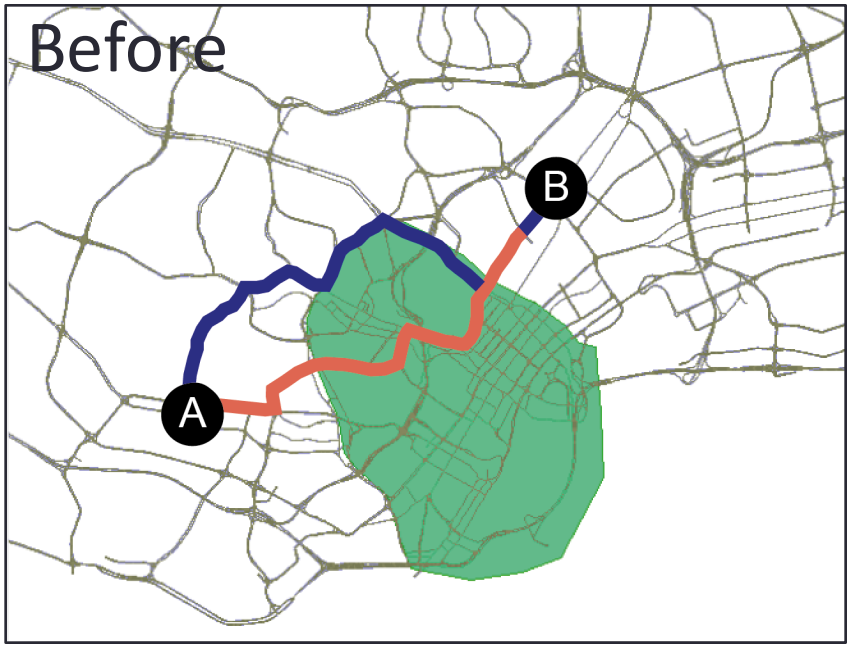


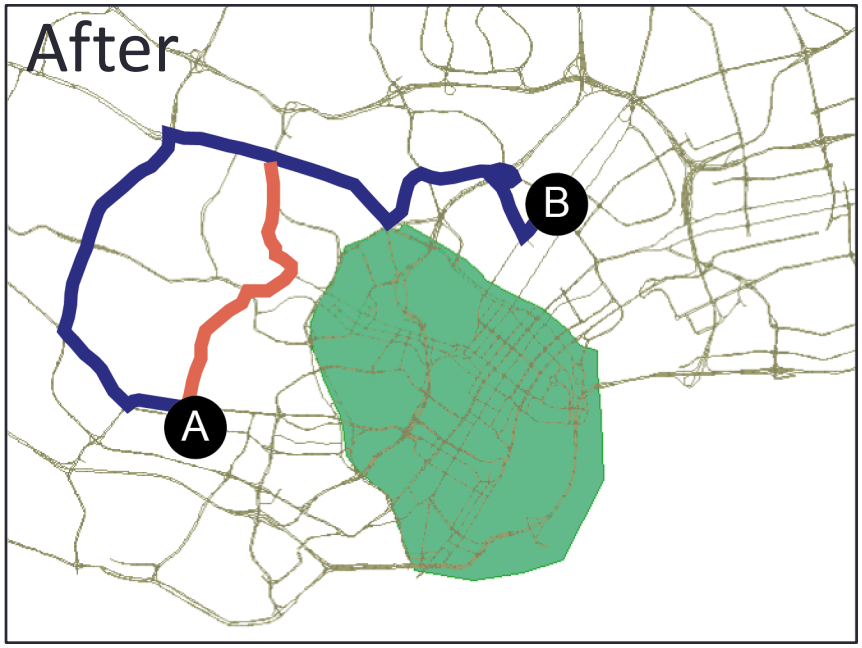
Results: Fleet Performance





Results: Network Performance





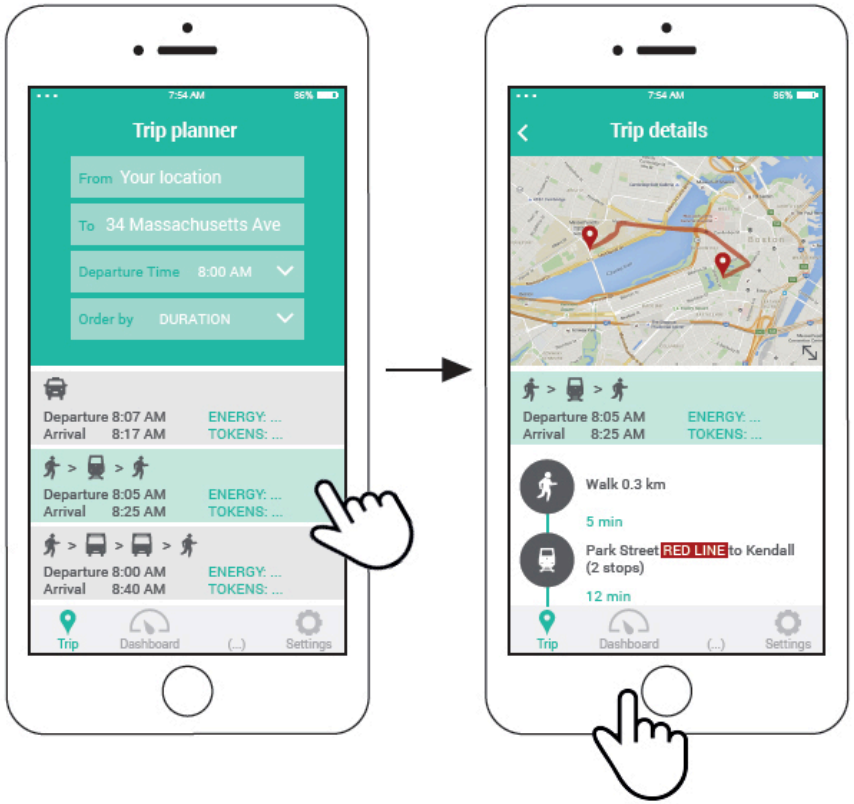
Path	Length	Travel Time	Share
1	10.6 km	17 min	13.0%
2	10.1 km	14 min	32.4%

Path	Length	Travel Time	Share
1	18.7 km	32 min	10.1%
2	15.4 km	29 min	25.3%

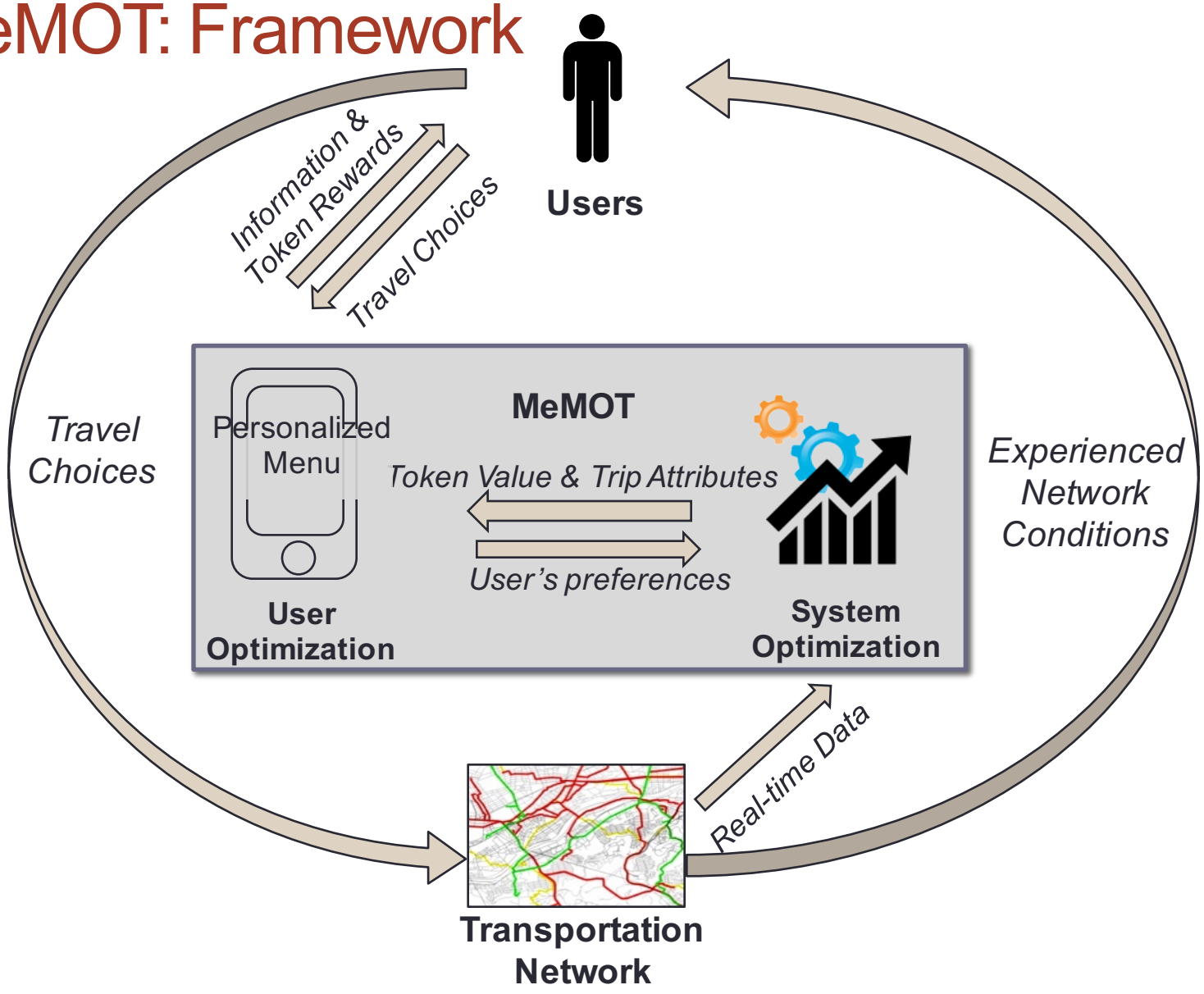
Mobility Electronic Market for Optimized Travel (MEMOT)

MeMOT: Concept

- **Optimized and personalized menu** with information and incentives in a trip planner app
- Incentives based on real-time **system optimization** predicting network conditions and energy savings



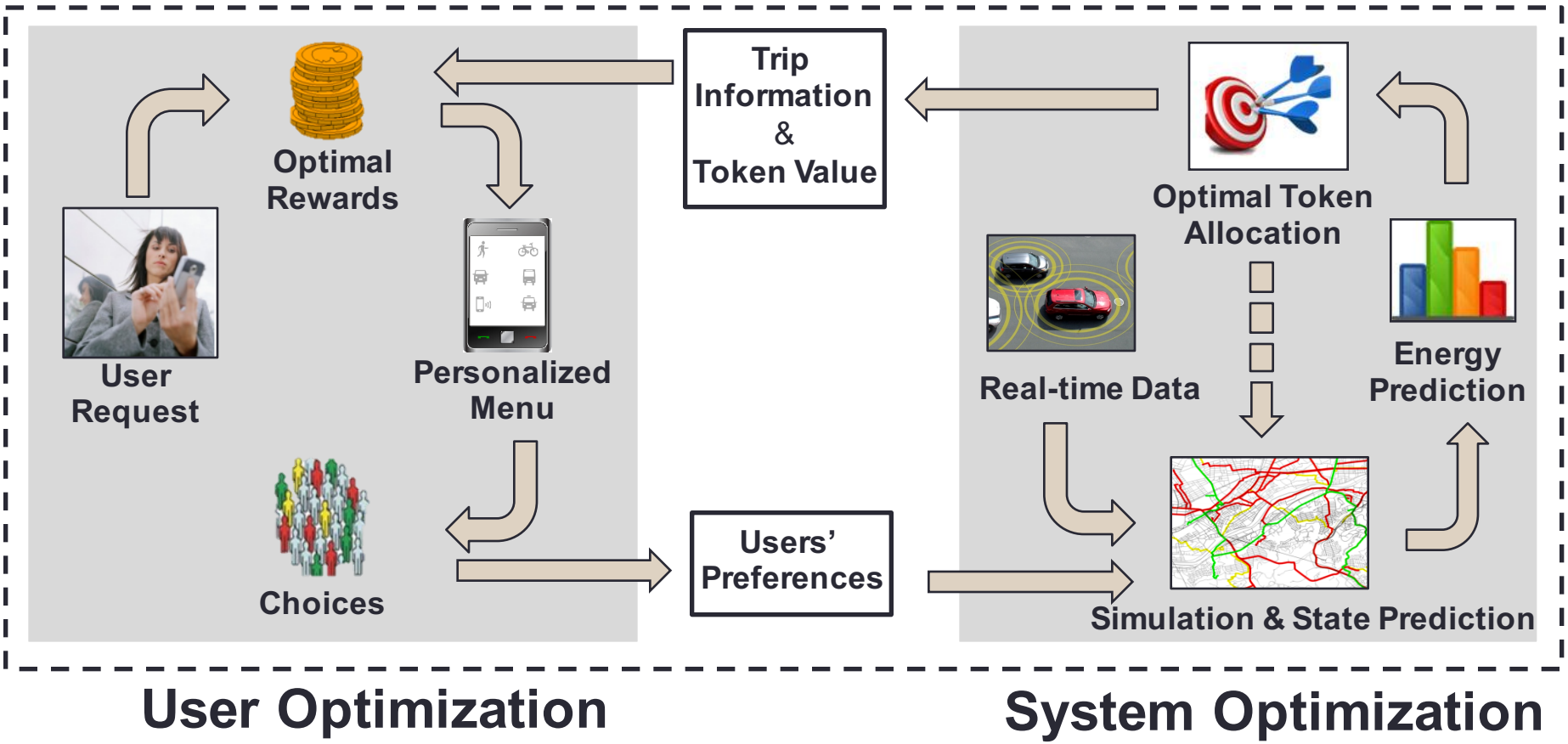
MeMOT: Framework



MeMOT: 2-Level Optimization

1. A simulation-based **system optimization** framework that predicts traffic, energy consumption and energy efficiency in real-time.
2. A **personalized menu optimization** with information and incentives integrated into an app-based travel diary

MeMOT: 2-Level Optimization Framework



Smart Mobility: Optimization and Behavioral Modeling

References (1)

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- Atasoy, B., Ikeda, T., Song, X. and Ben-Akiva, M. (2015), "The Concept and Impact Analysis of a Flexible Mobility on Demand System", *Transportation Research Part C: Emerging Technologies*, Vol. 56, pp. 373-392.
- Ben-Akiva, M., McFadden, D., and Train, K. (2015), Foundations of stated preference elicitation, consumer choice behavior and choice-based conjoint analysis.

References (2)

- Kamargianni, M., Matyas, M., Li, W., and Schafer, A. (2015). Feasibility Study for "Mobility as a Service" concept for London. Report prepared for the UK Department for Transport. Available at: https://www.bartlett.ucl.ac.uk/energy/docs/fs-maas-compress-final
- Lu, L., Yan, X., Antoniou, C. and Ben-Akiva, M. (2015), "W-SPSA: An Enhanced SPSA Algorithm for the Calibration of Dynamic Traffic Assignment Models", Transportation Research Part C, Vol. 51, pp. 149-166
- Lu, Y., Pereira, F. C., Seshadi R., O'Sullivan A., Antoniou, C., and Ben-Akiva, M. (2015), "DynaMIT2.0: Architecture Design and Preliminary Results on Real-time Data Fusion for Traffic Prediction and Crisis Management", IEEE 18th International Conference on Intelligent Transportation Systems
- Pereira, F. C., Rodrigues, F., and Ben-Akiva, M. (2013), "Text analysis in incident duration prediction", Transportation Research Part C: Emerging Technologies, Vol. 37, pp. 177–192

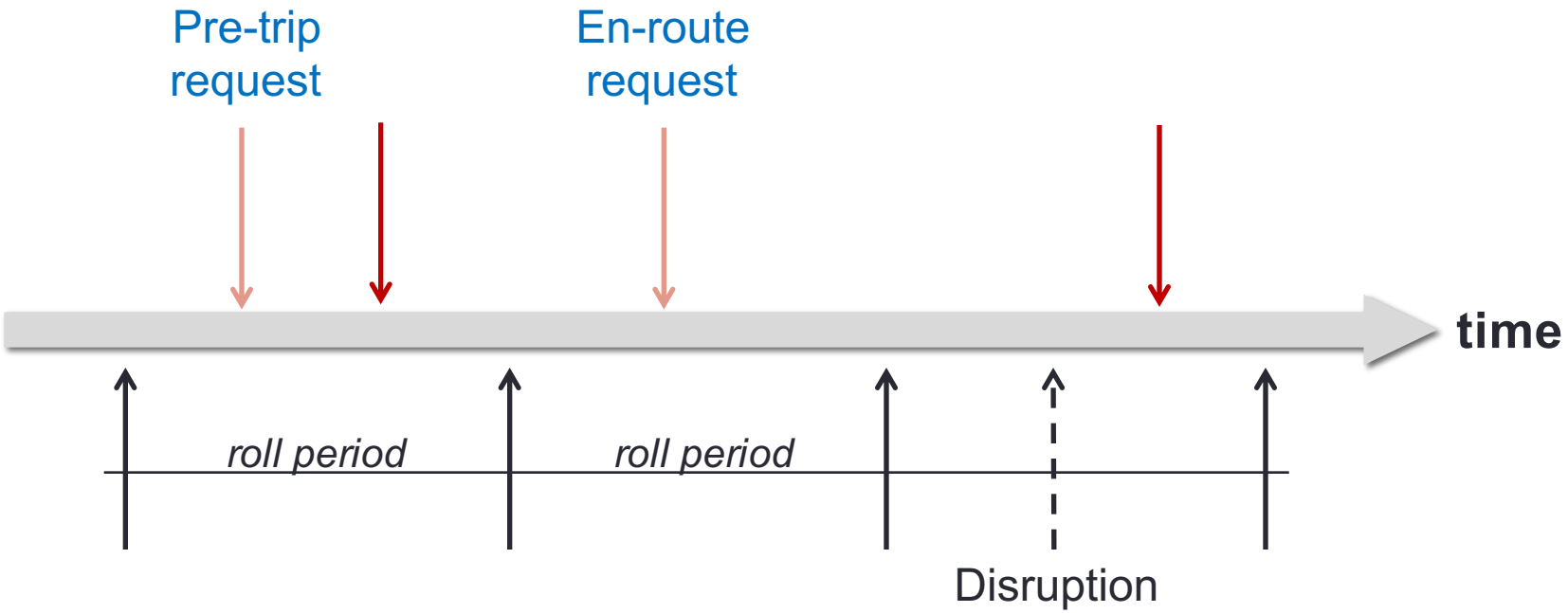
APPENDIX

MEMOT

MeMOT: 2-Level Optimization

User Optimization

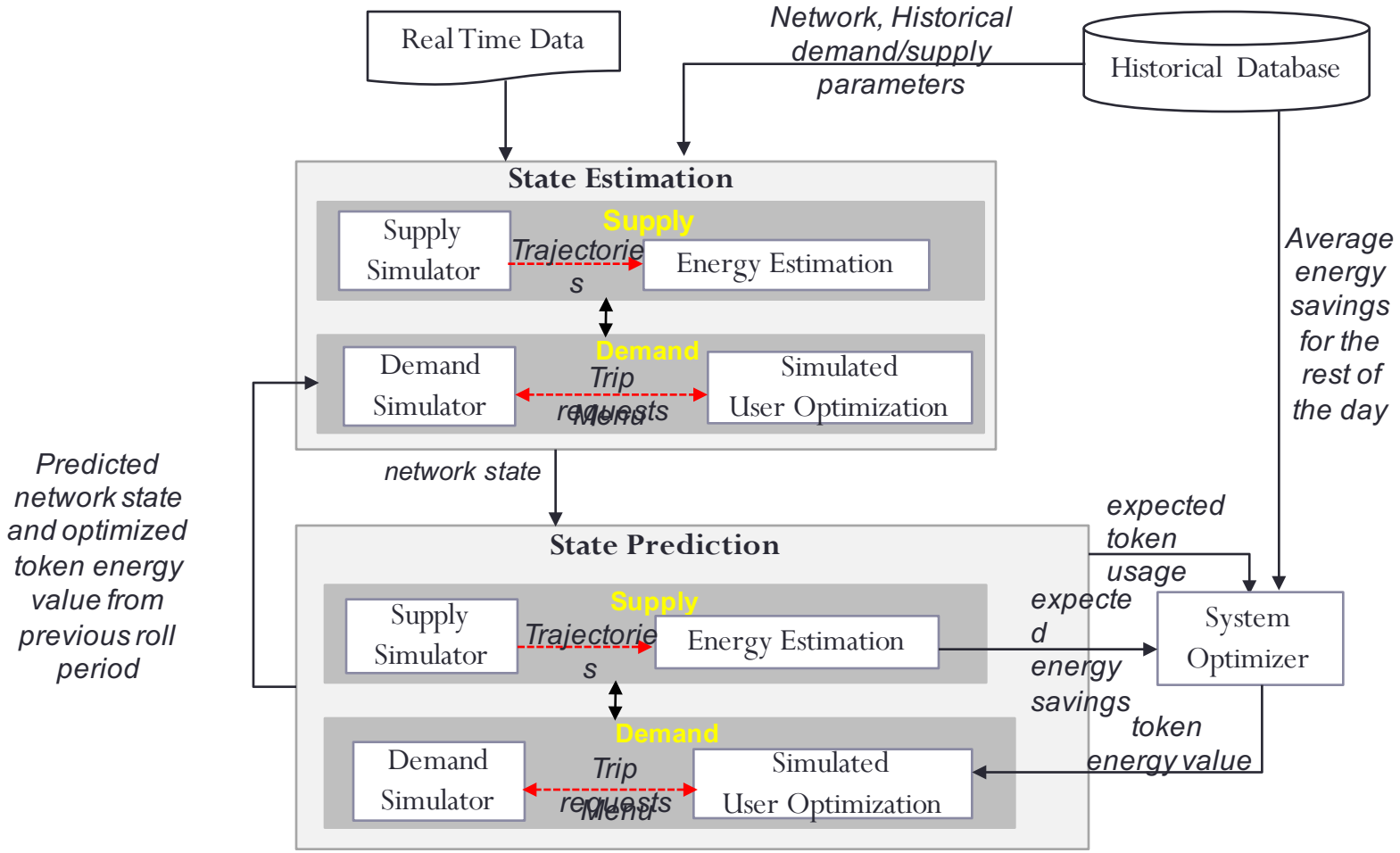
(user 1, user 2, …)



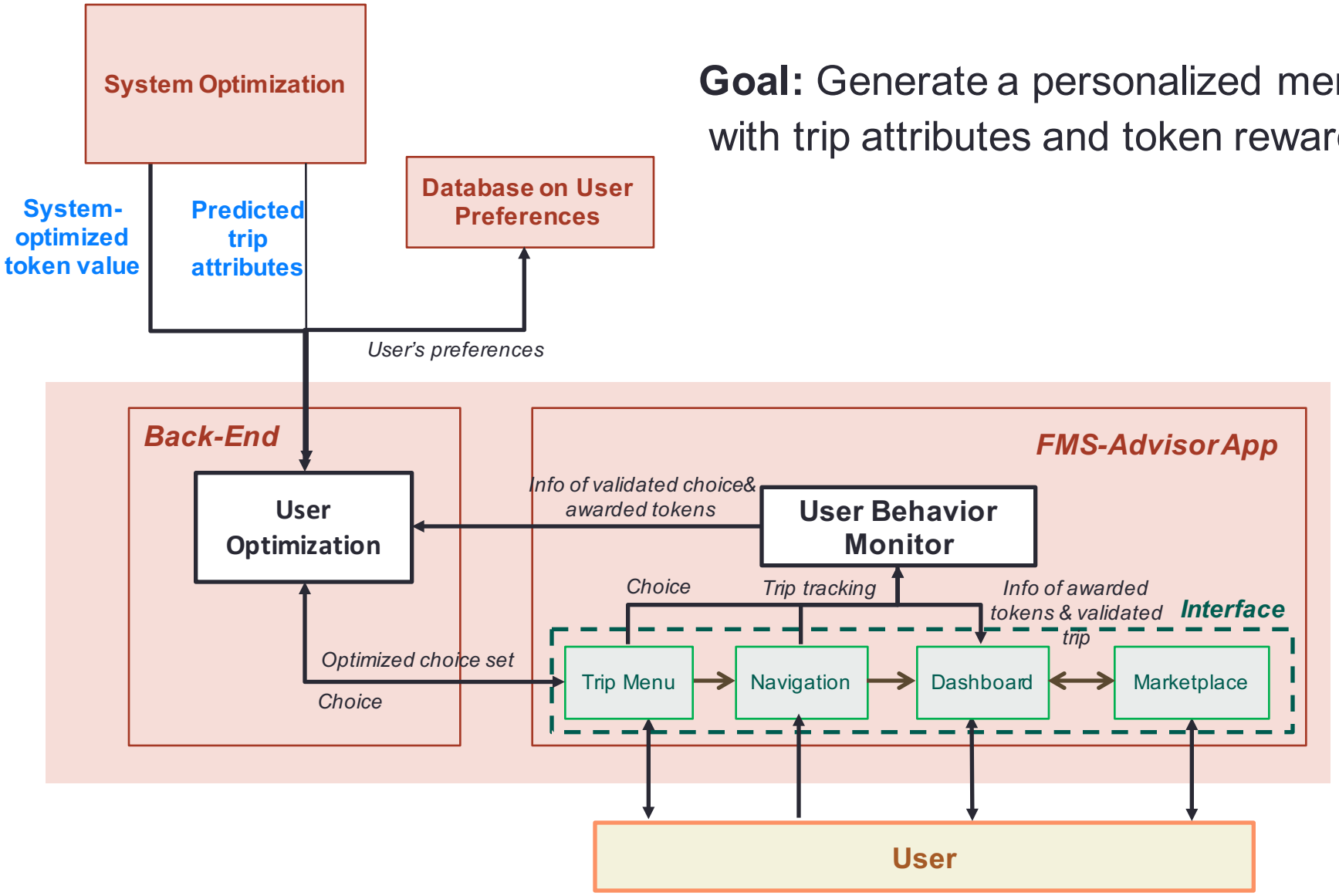
System Optimization

System Optimization

Goal: Generate reference token value and trip attributes for system-wide optimized scenario

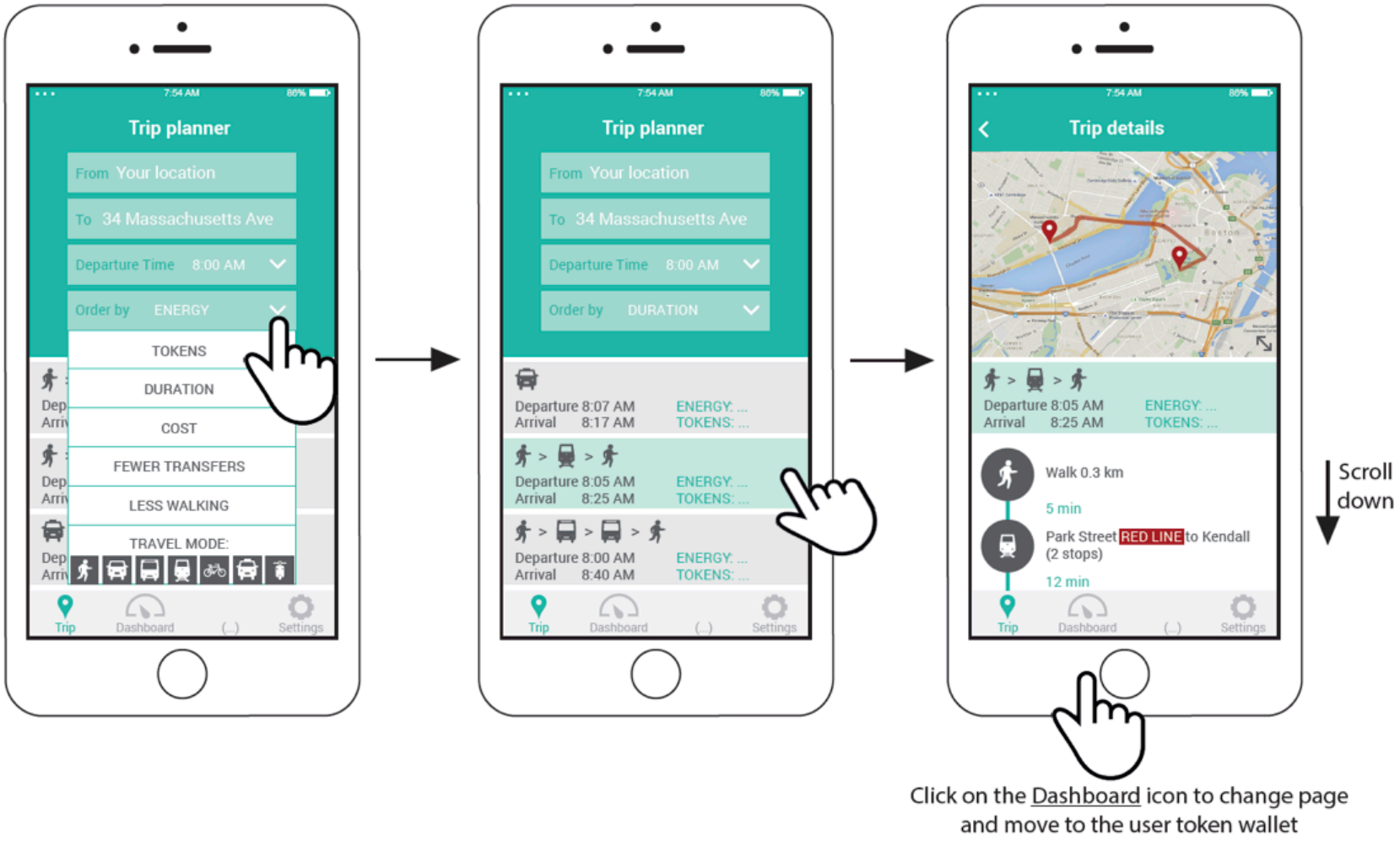


User Optimization



Goal: Generate a personalized menu with trip attributes and token rewards

Trip Menu


7:54 AM
86%
Trip planner
From Your location
To 34 Massachusetts Ave
Departure Time 8:00 AM
Order by ENERGY
TOKENS
DURATION
COST
FEWER TRANSFERS
LESS WALKING
TRAVEL MODE:
Trip
Dashboard
(...)
Settings
Trip planner
From Your location
To 34 Massachusetts Ave
Departure Time 8:00 AM
Order by DURATION
Departure 8:07 AM ENERGY: ...
Arrival 8:17 AM TOKENS: ...
Departure 8:05 AM ENERGY: ...
Arrival 8:25 AM TOKENS: ...
Departure 8:00 AM ENERGY: ...
Arrival 8:40 AM TOKENS: ...
Trip details
Departure 8:05 AM ENERGY: ...
Arrival 8:25 AM TOKENS: ...
Walk 0.3 km
5 min
Park Street RED LINE to Kendall
(2 stops)
12 min
Scroll down
Click on the Dashboard icon to change page
and move to the user token wallet

FMS Platform