Efficient agent-based model of network trip flow with general demand pattern

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TRB Workshop on Traffic Simulation and CAV Modeling
18th November 2020

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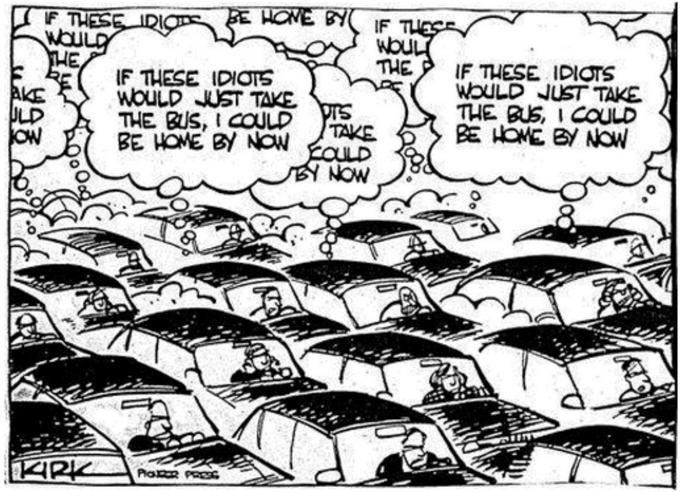
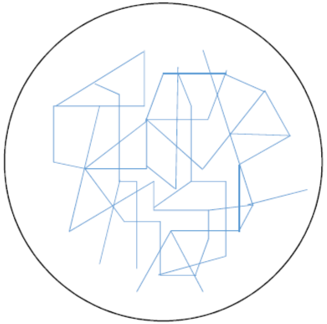
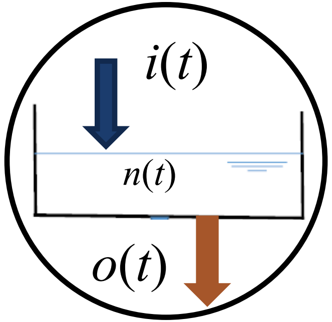
Traffic congestion



- Increased travel times
- Pollution
- Car accidents

Network modeling

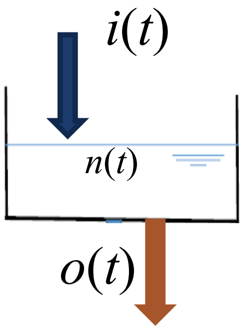




- Tracks inflow and outflow of a "bathtub"/ "single reservoir"
- Accumulation of vehicles $n(t)$ is the only variable

Vickrey (1991, 2020)

Bathtub model for traveling trip dynamics

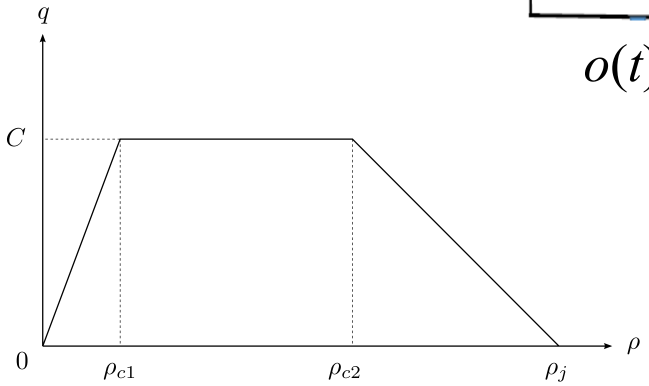


SUPPLY:

Network fundamental diagram:

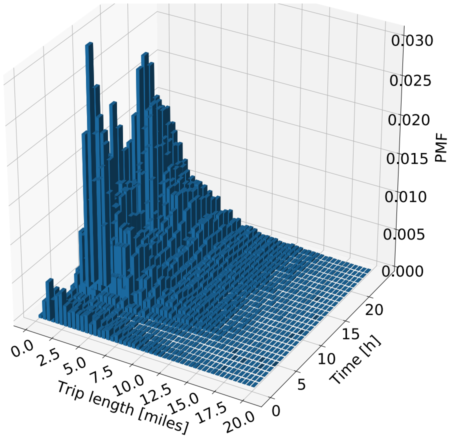
$$v(t) = V(\rho(t))$$

Assumption: Trapezoidal



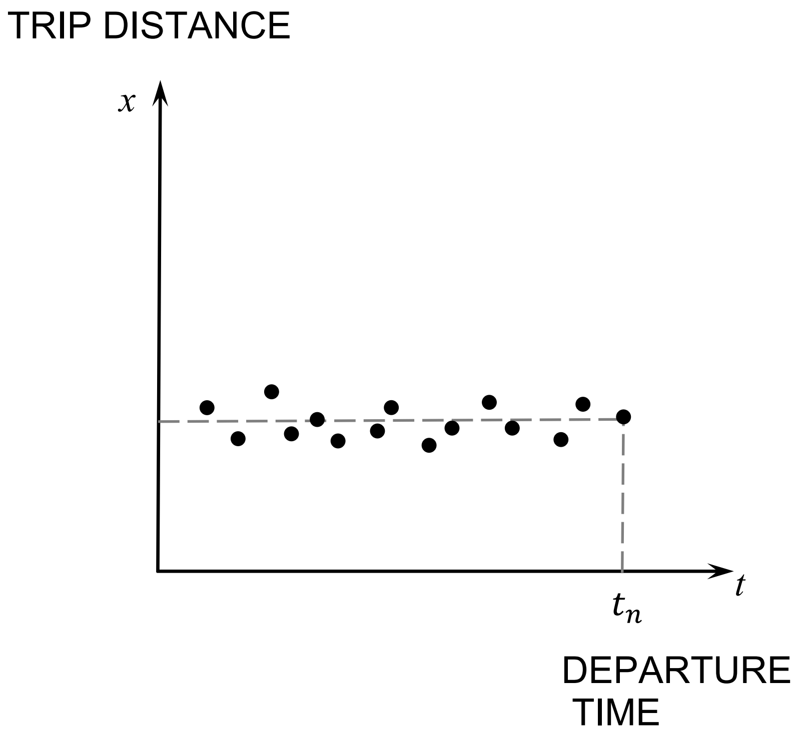
DEMAND:

Distribution of trip distances: $\widetilde{\Phi}(t, x)$



DEMAND TYPE

- The demand is defined by trip distance and departure time
- Could be known, or a distribution



Vickrey's bathtub model

Vickrey (1991, 2020)

- ASSUMPTION on Trip Distance

→ time-independent negative exponential distribution

Dynamics modeled with ODE

$$\dot{n}(t) = i(t) - \frac{B\,k(t)V\big(k(t)\big)}{\bar{L}}$$

Small and Chu (2003)

Daganzo (2007)

What if the trip distance follows another distribution?

Generalized bathtub model

Jin (2020)

- Can handle any trip distance
- Completion rate: $\mathrm{o(t)} = V\big(k(t)\big)\frac{\partial}{\partial x}Y(t,0)$
- Dynamics (PDE)

$$\frac{\partial}{\partial t}Y(t,x) - V\big(k(t)\big)\frac{\partial}{\partial x}Y(t,x) = i(t)\,\widetilde{\Phi}(t,x)$$

$Y(t,x)$: active traveling trips with remaining FHV distance not smaller than x

$n(t) = Y(t,0)$: total number of active traveling trips

$k(t)$: density of vehicles in the network

LIMITATIONS

Continuum modeling

- Deterministic demand

  → Exact solution

- Probabilistic demand

  → No information of higher order momentum

  → Approximate solution

METHODOLOGY

02

AGENTS

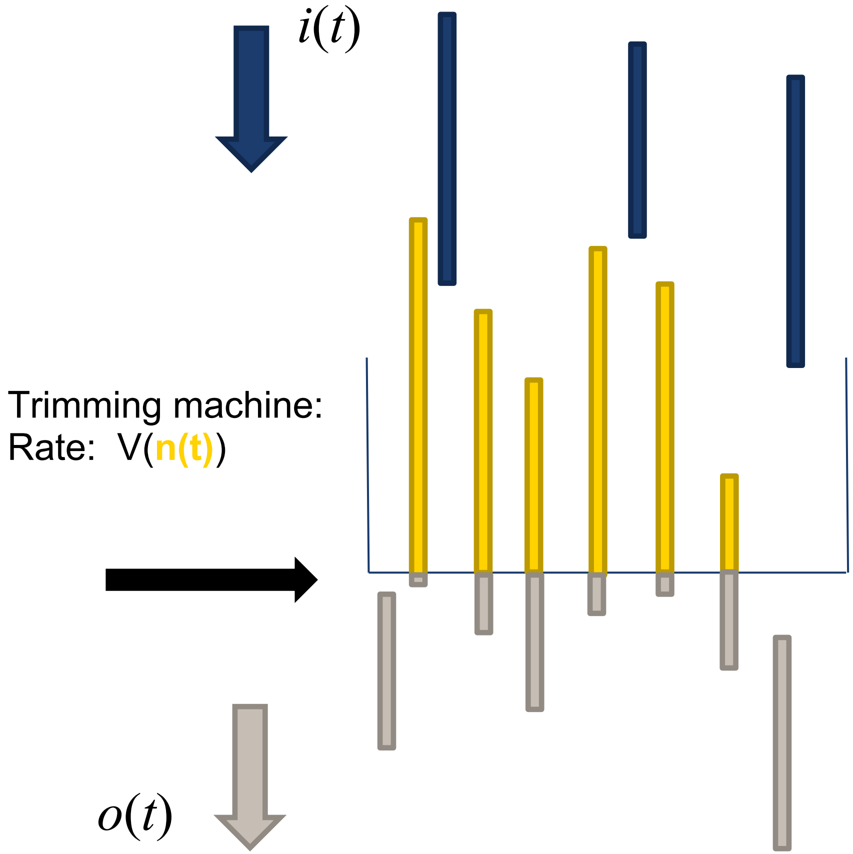
- DEPARTURE TIME
- TRIP DISTANCE
- OTHER ECONOMICAL CHARACTERISTICS (if needed)

METHODOLOGY

02

Same idea, but more detail

- We have a bathtub
- The demand is defined by individual trips
- The progression can be tracked

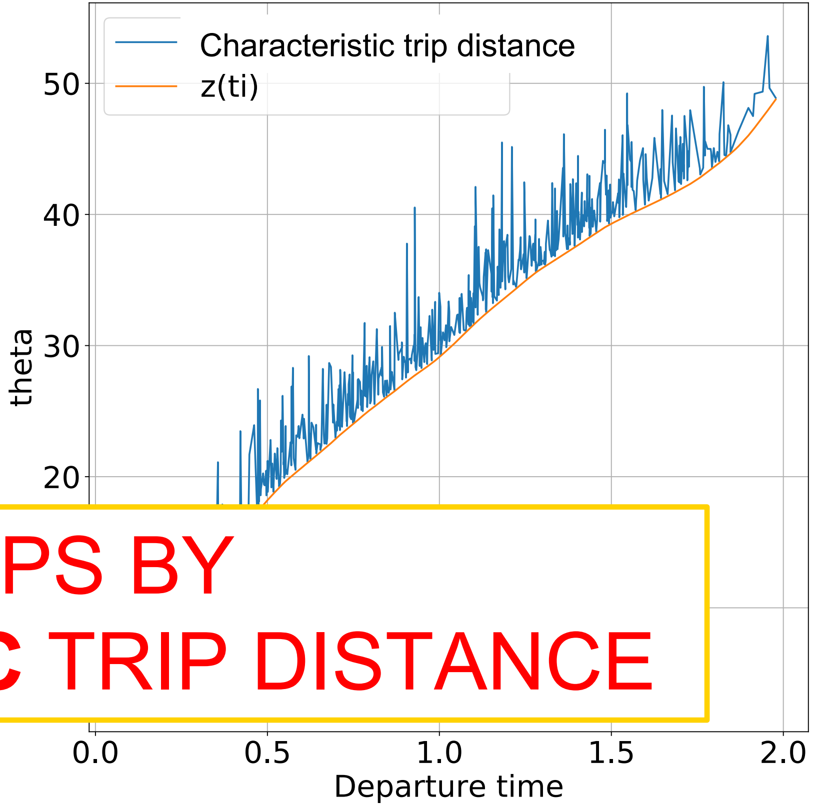


02

CHARACTERISTIC DISTANCE

- Define z(t)
- Characteristic distance of trip *i*

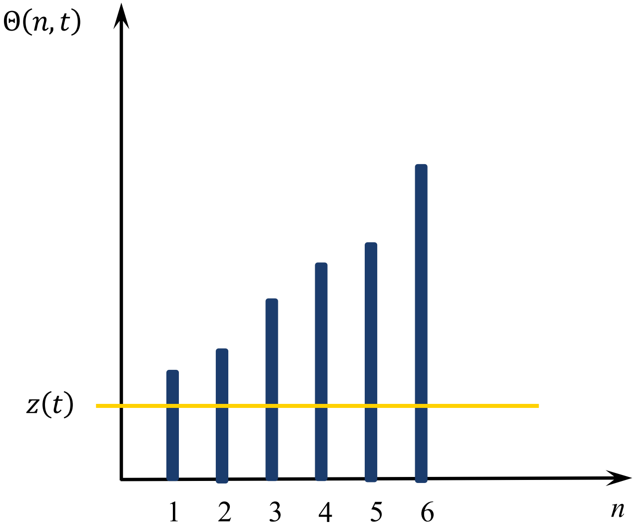
$$\theta_i = x_i + z(t_i)$$

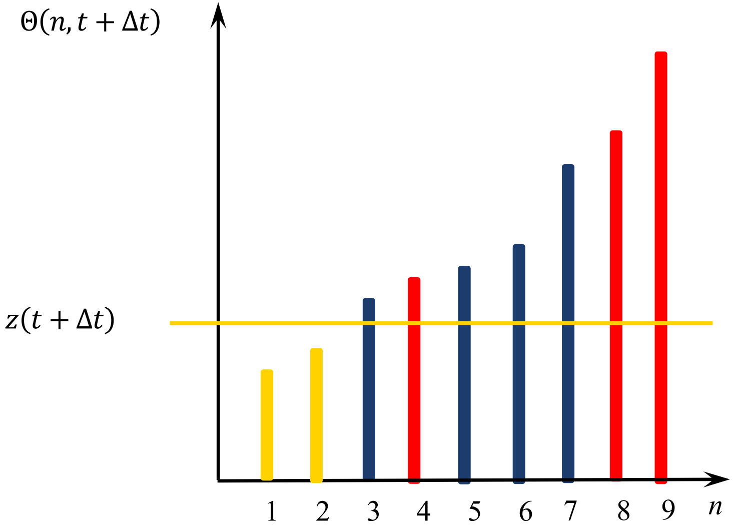


SORT ACTIVE TRIPS BY **CHARACTERISTIC** TRIP DISTANCE

02

METHODOLOGY





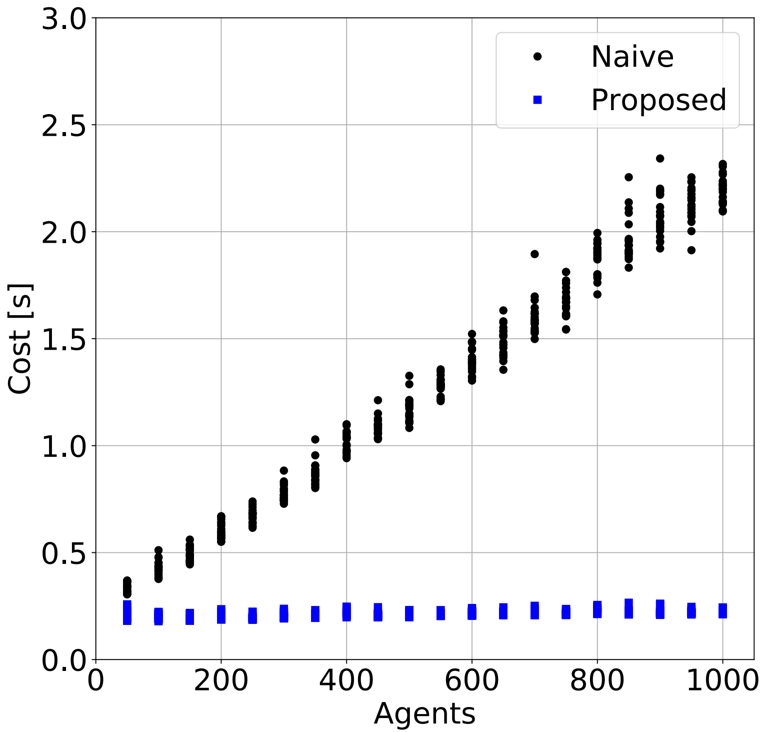
METHODOLOGY

02

1st CONTRIBUTION

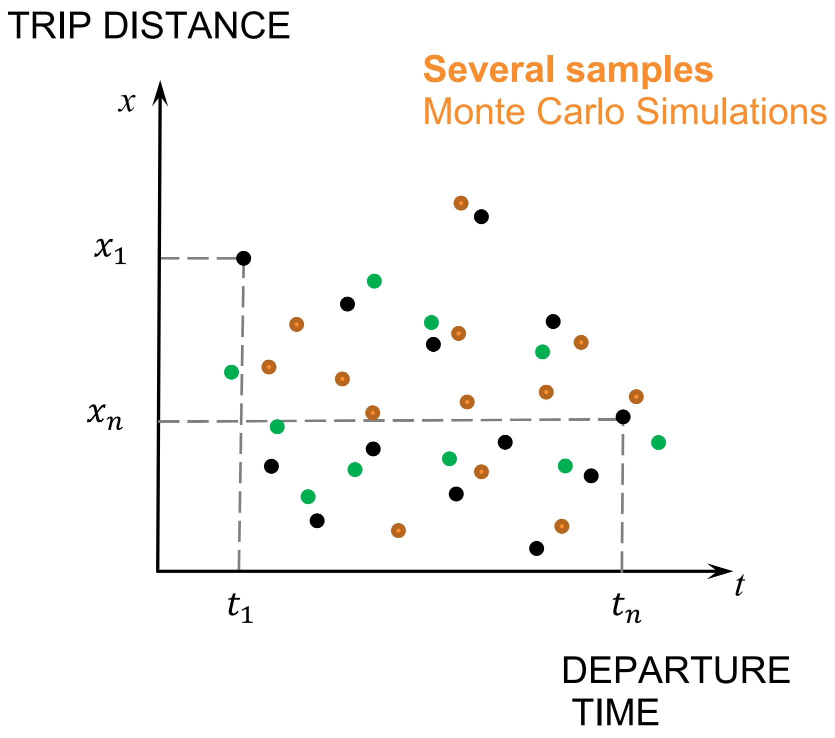
Efficiency

- Naïve: without sorting
- Proposed: with sorting



DEMAND TYPE

- Discrete
- Continuous
- Probabilistic



2nd CONTRIBUTION

INDEPENDENT OF CITY SIZE

Model can be **normalized**

- 1 Mio agents in a city with 1000 km
- 1000 agents in a city of 1 km

If the demand “pattern” is equal.

NUMERICAL RESULTS: speed evolution

Total demand: 320 veh/km/ln ; trapezoidal inflow

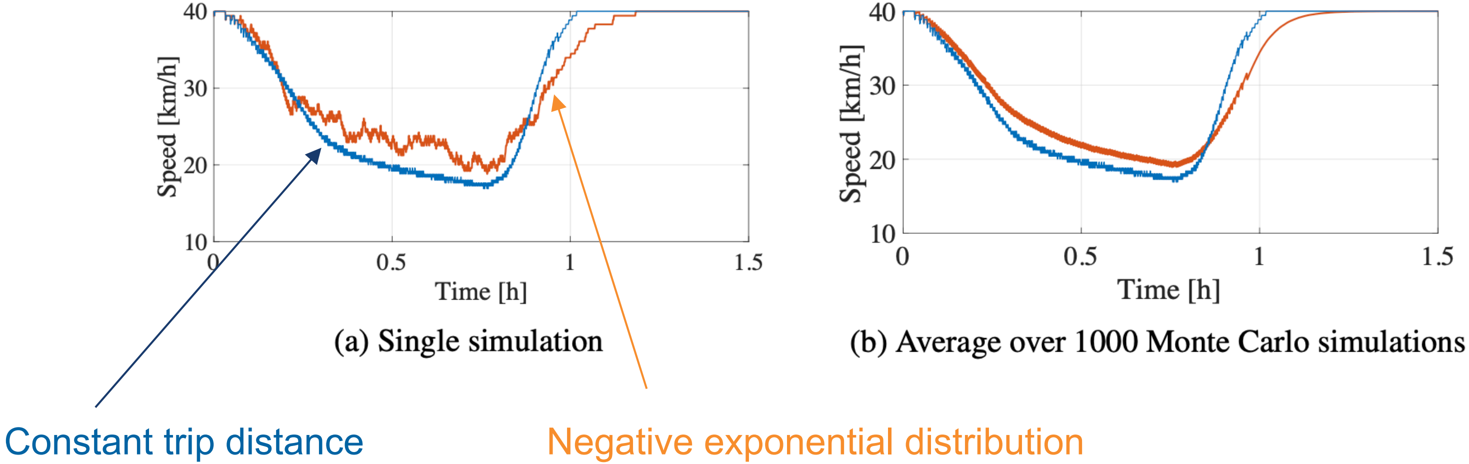
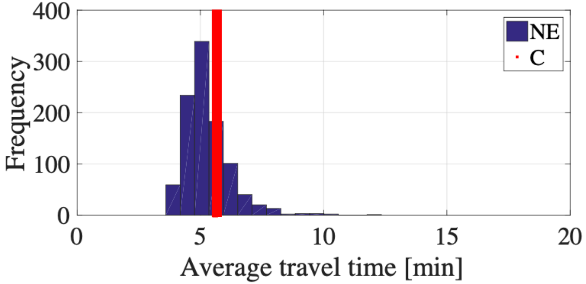


Figure 1: Speed evolution over time for two types of TDD with the same average trip length of B = 2 km. The constant trip distance (blue), and the time-independent negative exponential trip distance distribution

NUMERICAL RESULTS: individual trip information

- **Negative exponential distribution**: Different samples lead to different results (probabilistic)
- **Constant distance**: Few variation across simulations (deterministic)

MONTE CARLO SIMULATIONS



RESULTS ANALYSIS

03

CONTRIBUTIONS

1. Captures individual trip information
2. Computationally efficient
3. Can be normalized
4. More accurate than generalized bathtub model for stochastic demand

CONCLUSIONS

- Solution for any demand
- Efficient and accurate to model traffic congestion
- Can be extended to more complex systems with shared mobility

THANKS

Does anyone have any questions?

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