Segregating Buses and Cars in a Congested, Non-Steady State Network

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August 12th, 2014

Motivation: Effects of Bus-only Lanes on Car Traffic

- Bus-only lanes to enable buses to bypass car queues

- In settings where space is limited, convert regular use lanes to bus-only

Downside of Lane Conversions

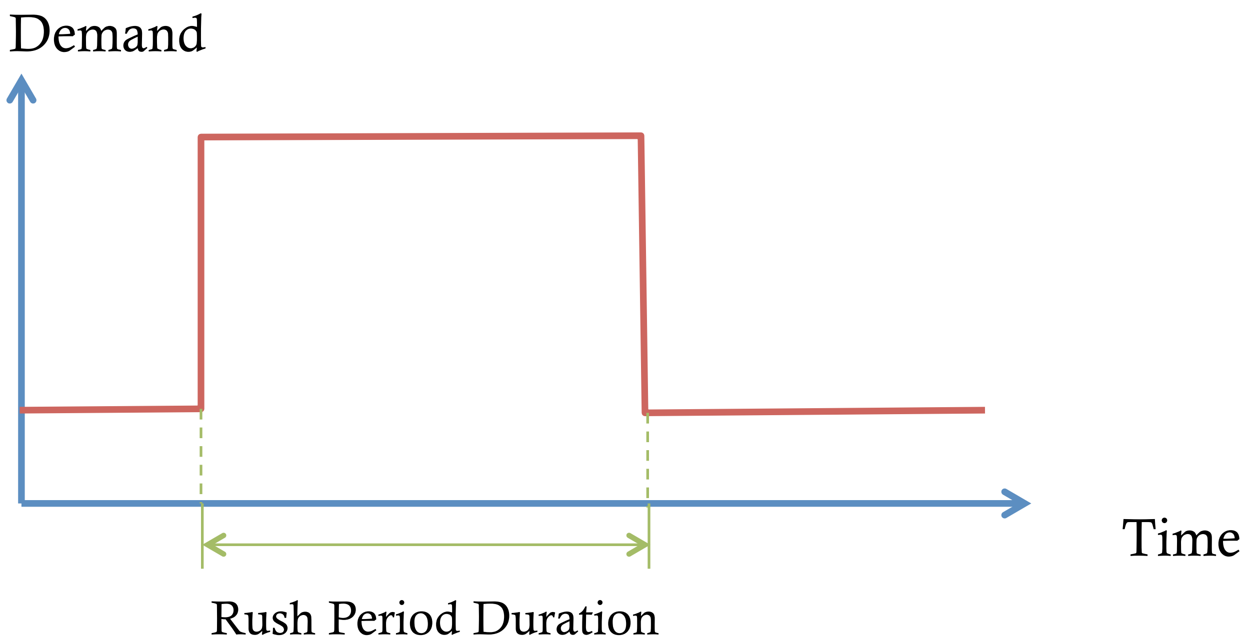
- Lane conversions can be damaging to car traffic
- Fear of negative impacts on car traffic has led to opposition to lane conversion proposals

Previous Research Findings

- Yet, previous research (ISTTT 18) has shown that such lane conversions can diminish car delays due to the **smoothing effect**
- This previous work assumed:
  - network traffic operated in **steady-state conditions**
  - bus lanes are reserved for the entire duration of the analysis

Present Work

- We further explore impacts of lane conversions in **non-steady state conditions:**



Findings

We find that both car and bus traffic can benefit from converted bus lanes, if:

- The conversion persists only for the duration needed to serve rush-period bus schedules,
- And if beyond the end of bus tours, lanes are returned to general use

Findings

The favorable predictions hold even **without accounting for the smoothing effect,**
and even if **no travelers shift from cars to buses**

Why Do Benefits Arise?

Benefits arise because once all lanes are returned to cars, they enjoy **higher trip completion rates.**

This occurs because:

(1) Buses move faster → Buses complete their tours earlier in the day → **Cars enjoy a network free of buses early on in the day**

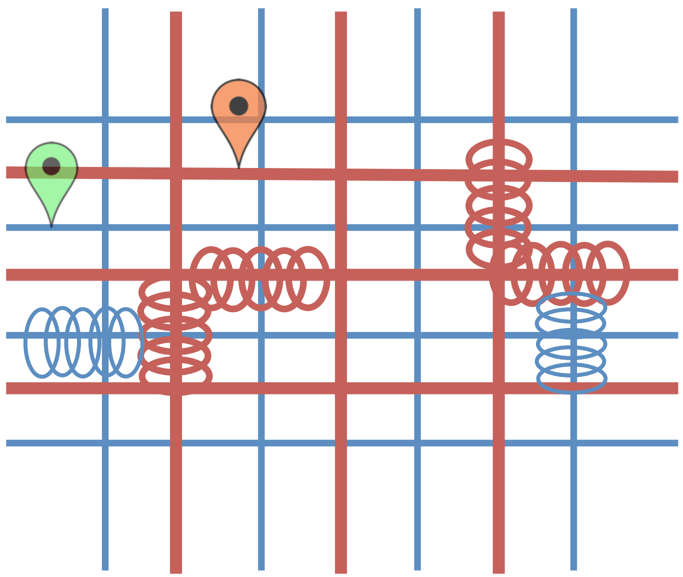
(2) Bus lane conversions cause more cars to queue outside the network → During the rush, the car accumulation inside the network is smaller → **Cars confront lower network accumulations**

Outline

1. **Model**
2. **Numerical Analysis**
3. **On-going Work**

City Structure

2 superimposed grid networks of arterial and local roads



Local Roads Network

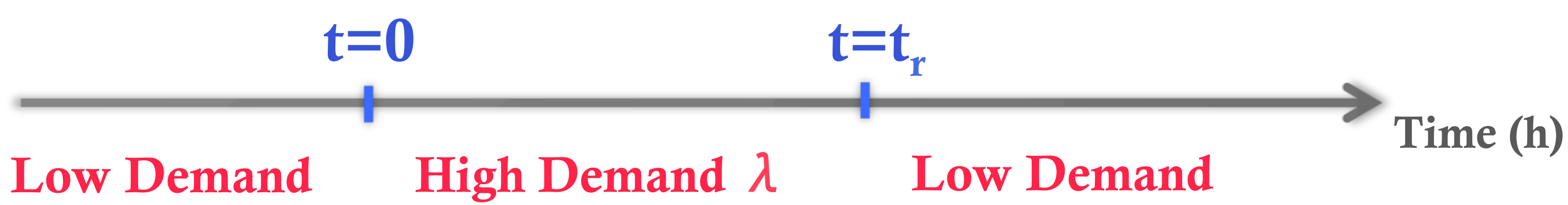
Arterial Roads Network

Example Origin for Car Trips (Local Roads)

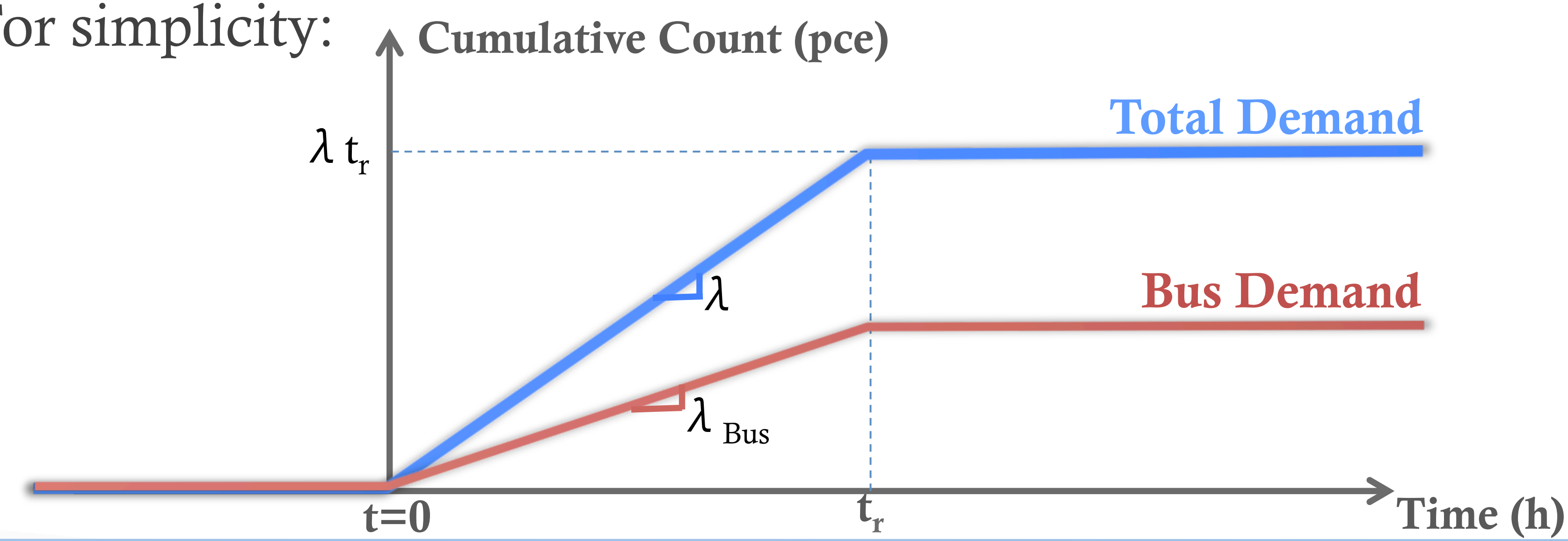
Example Origin for Bus Trips (Bus Depot along the Arterial)

Demand Pattern

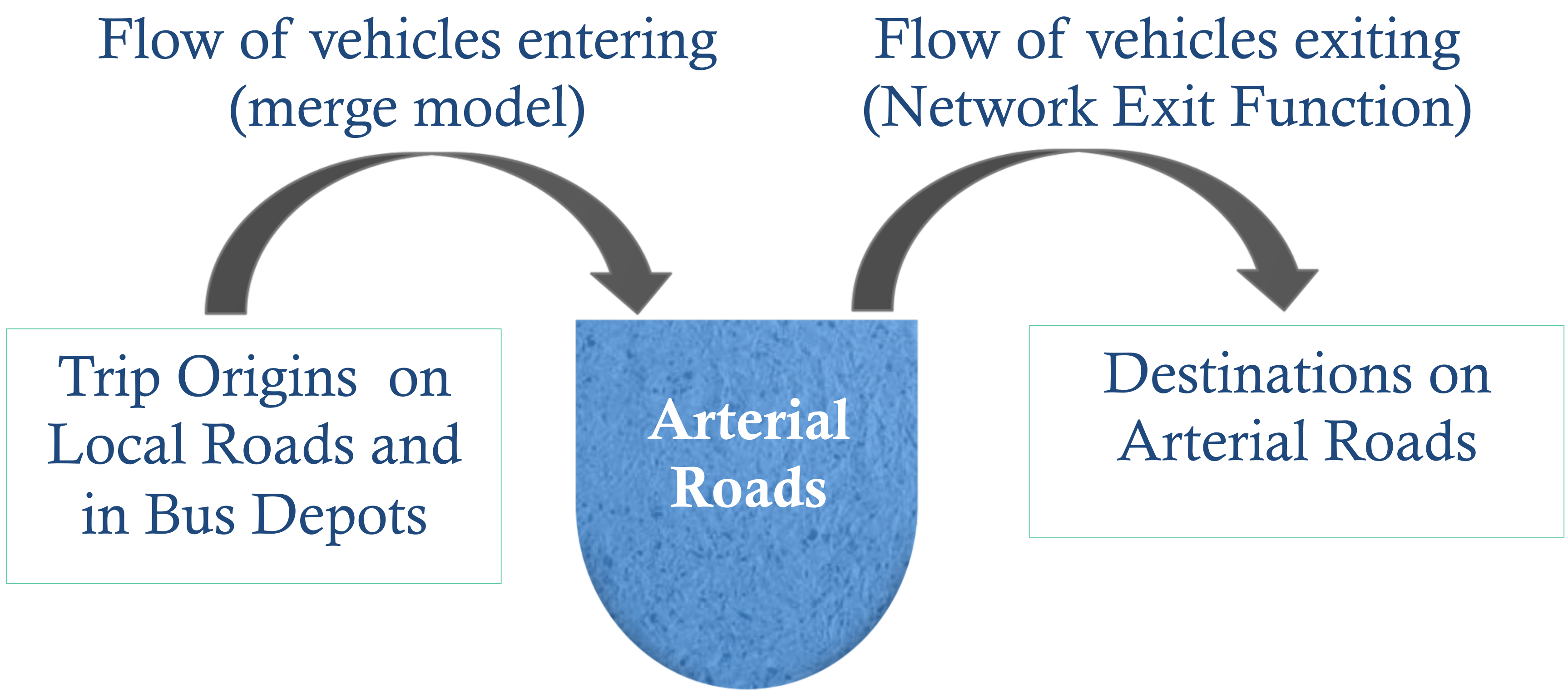
Rush Period t_r is the period of peak demand



For simplicity:

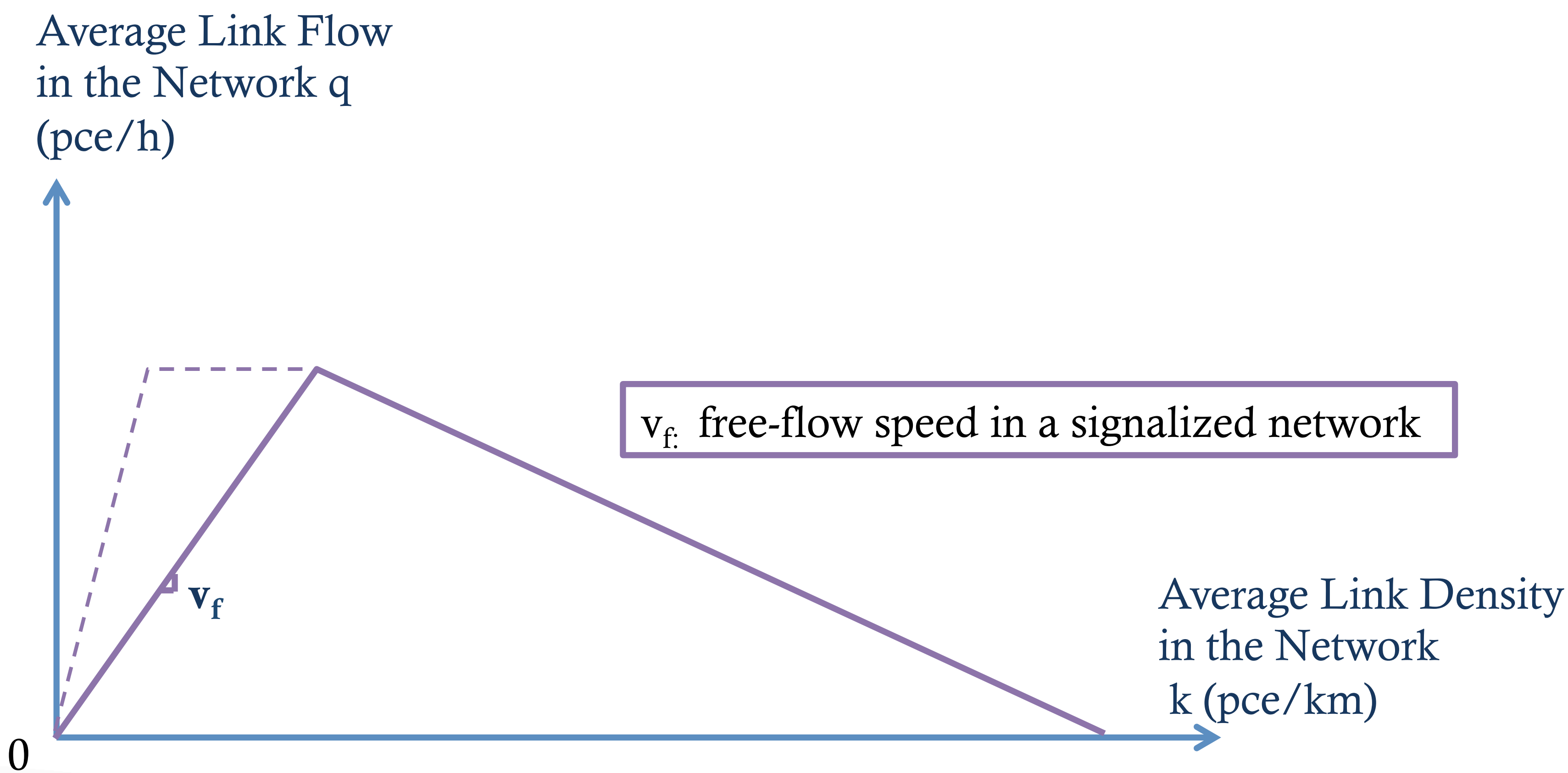


The Bin Model



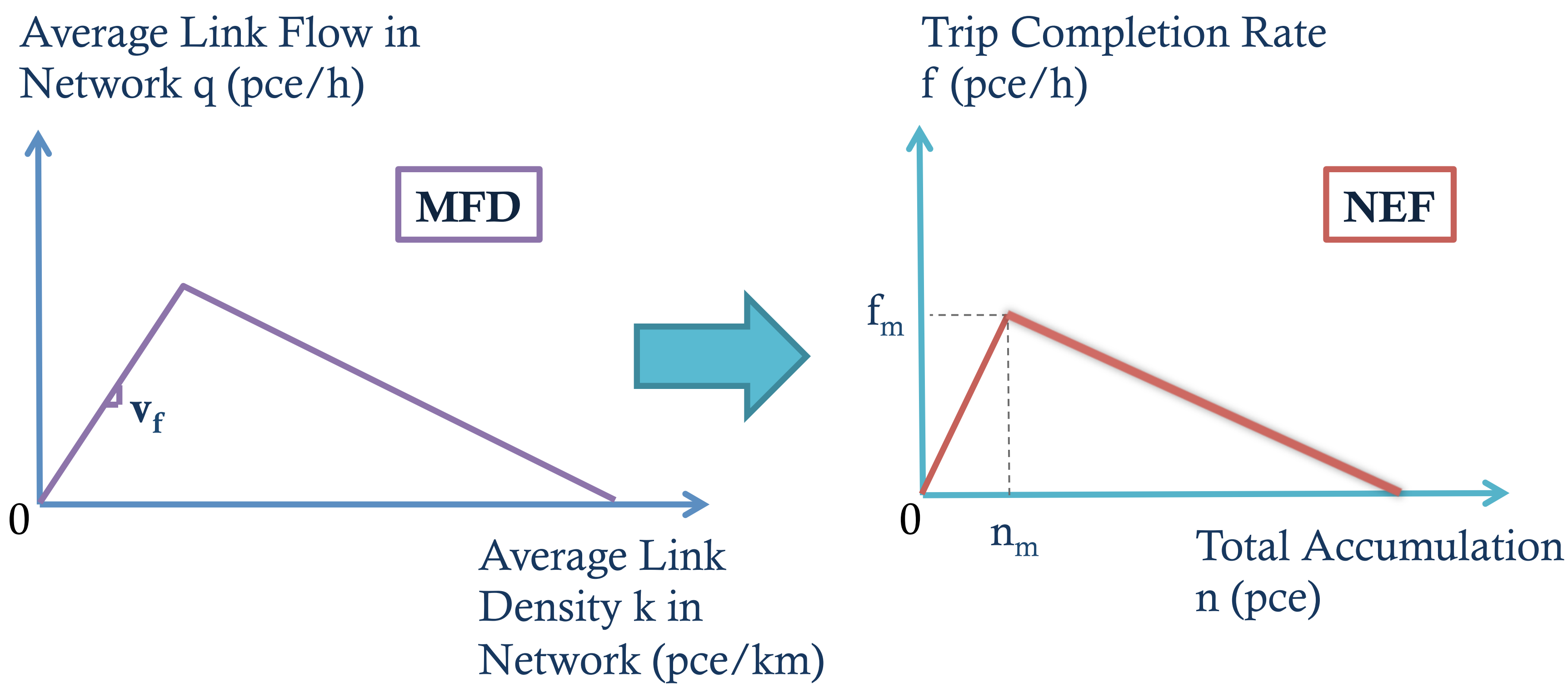
Macroscopic Fundamental Diagram (MFD)

Existence of a MFD in the network (e.g., Geroliminis and Daganzo, 2009)



Network Exit Function (NEF)

The MFD can be rescaled to a NEF (Daganzo, 2007)



Implicit Assumptions

1. **Same average vehicle trip length across both vehicle classes**

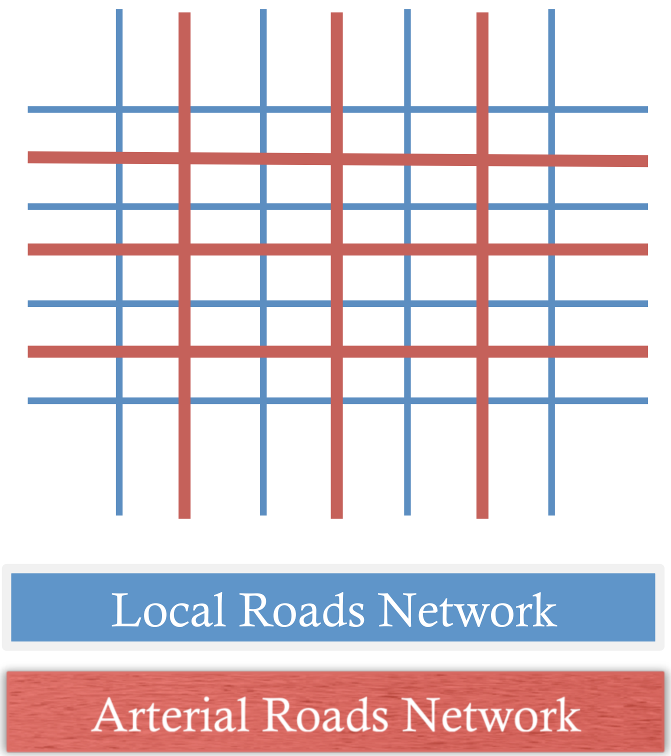
   → problematic, to be addressed later

2. **Same average speed across both vehicle classes**

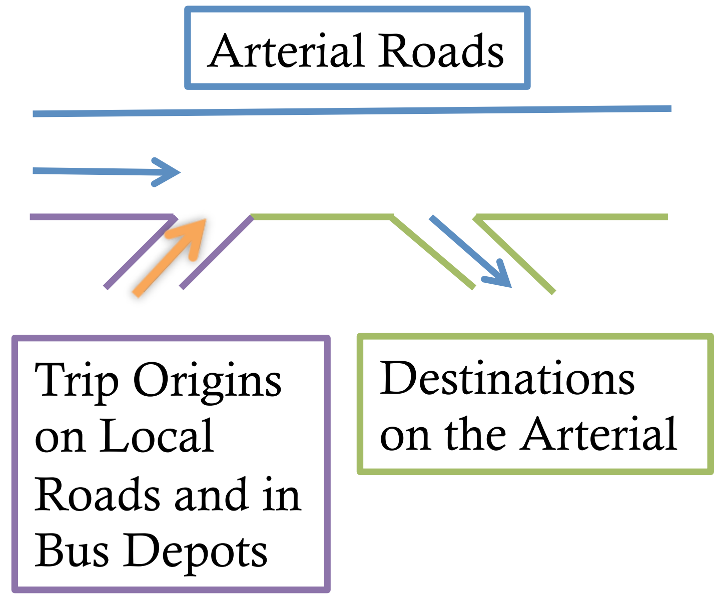
   → conservative

Flow of Vehicle Entering the Arterial Network

Grid Network



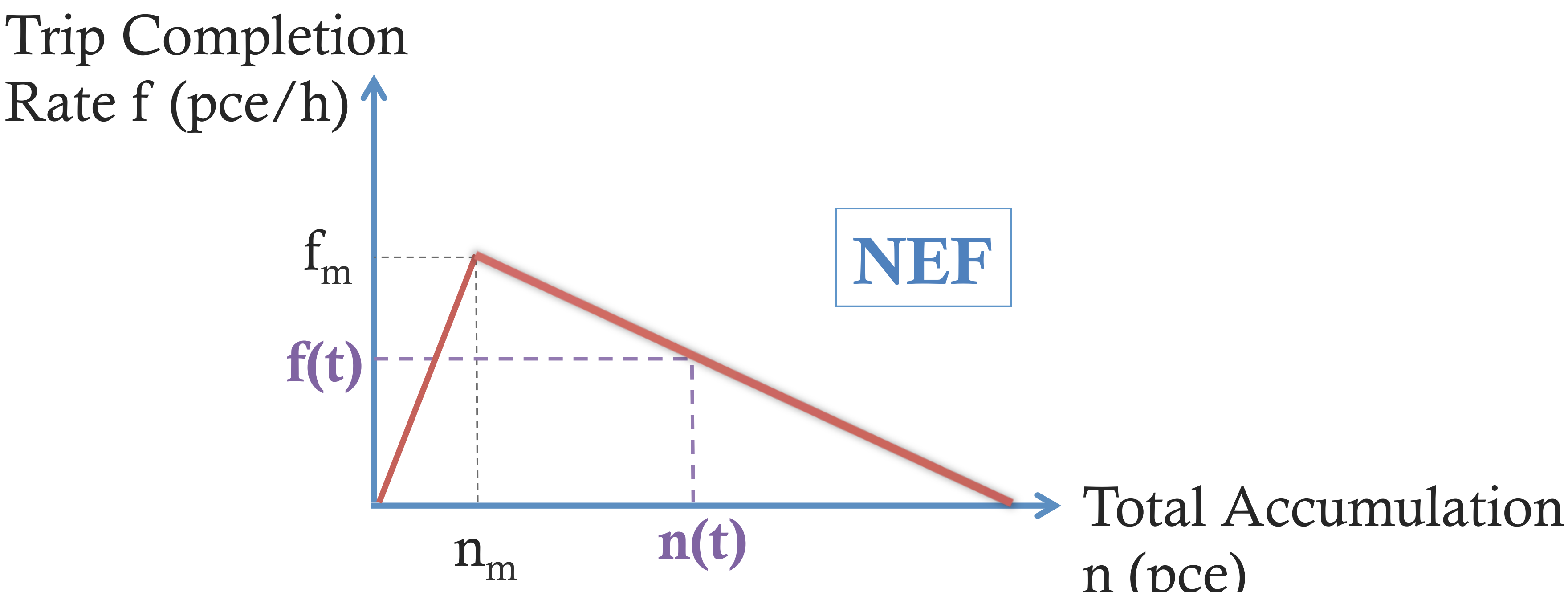
Building Block Representation



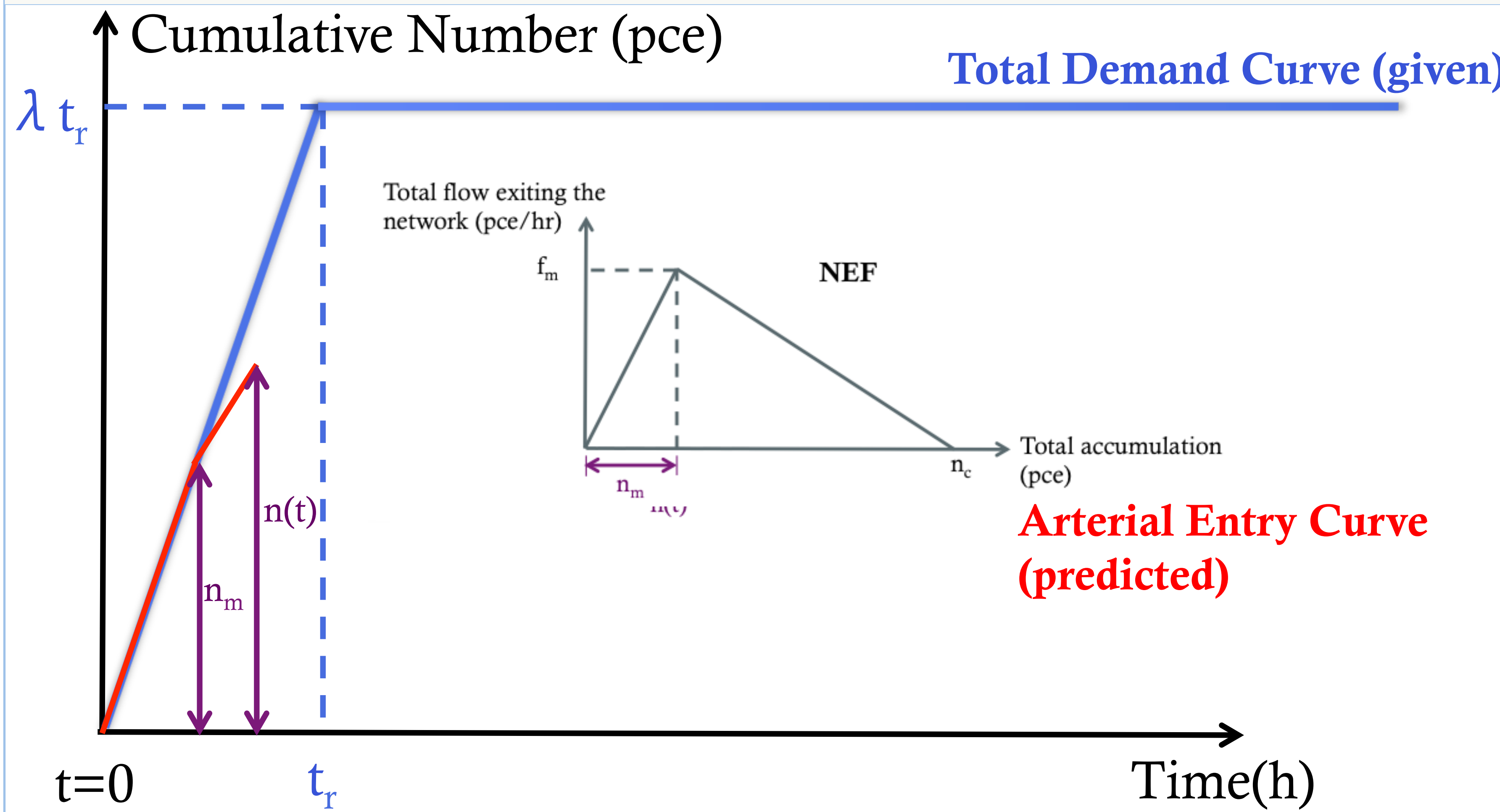
Merge Model (Daganzo, 1996)

Determining Accumulation in the Network

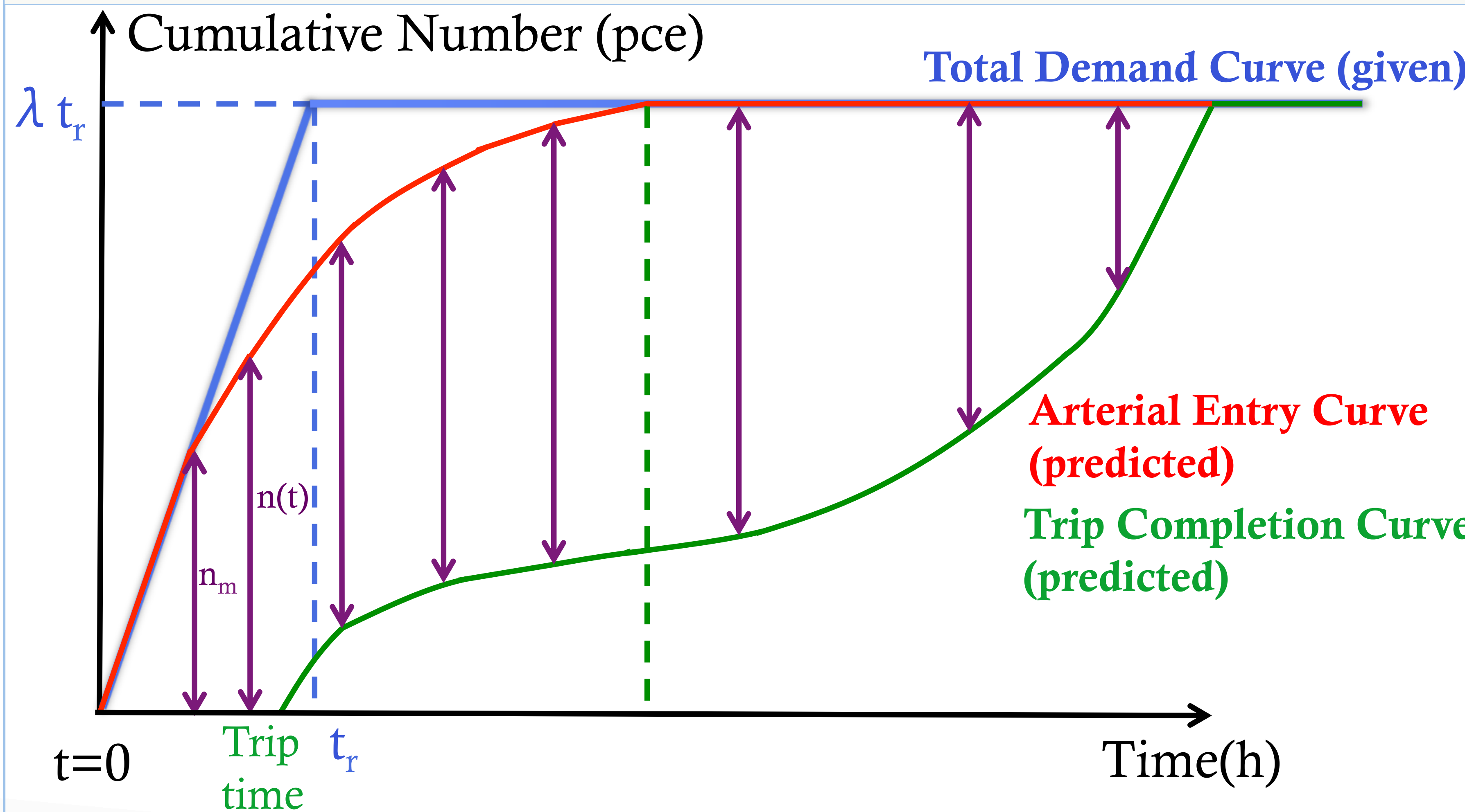
With the entry flows onto the arterial network determined from the merge model:



Queuing Diagram: Non-Segregated Case



Queueing Diagram: Non-Segregated Case



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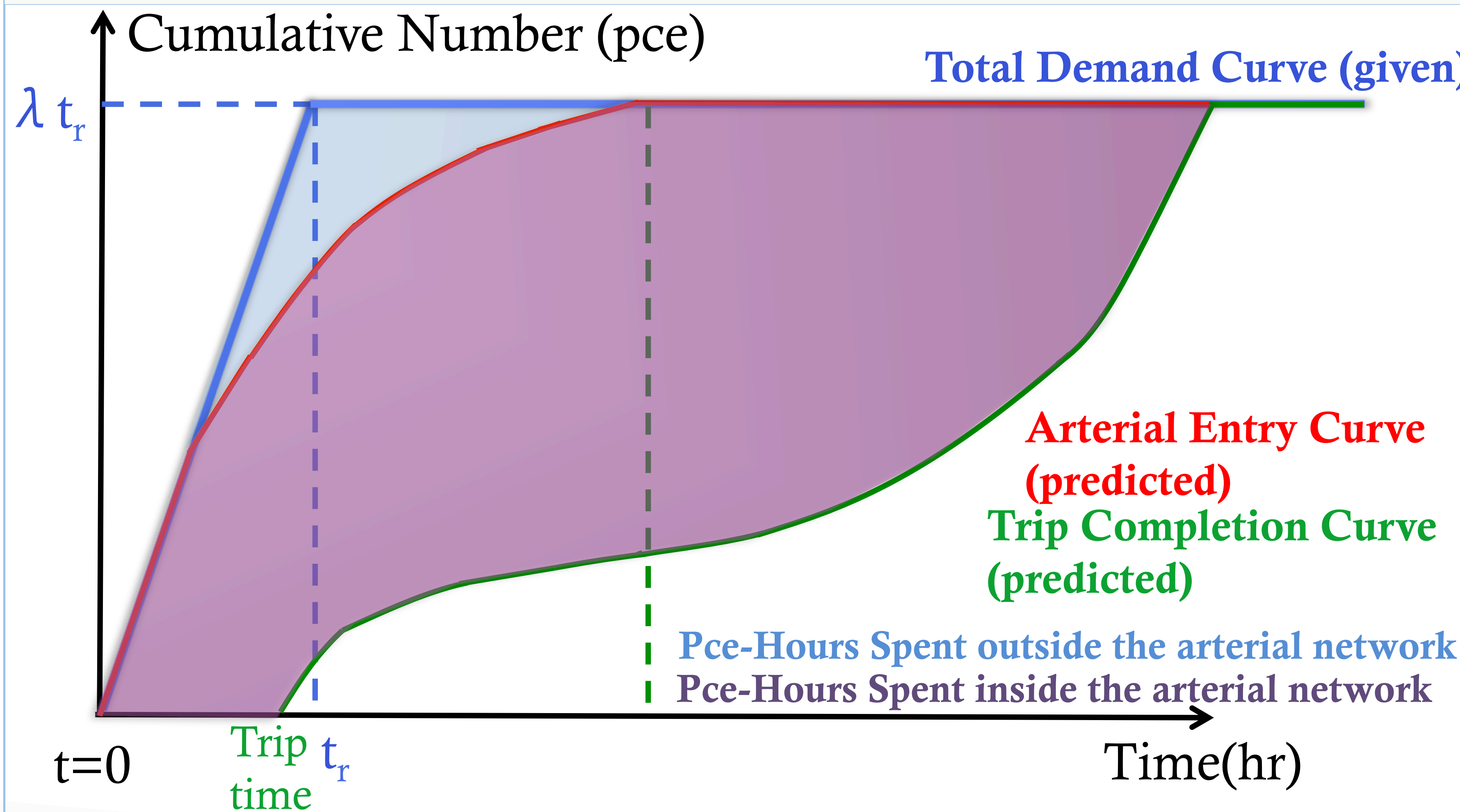
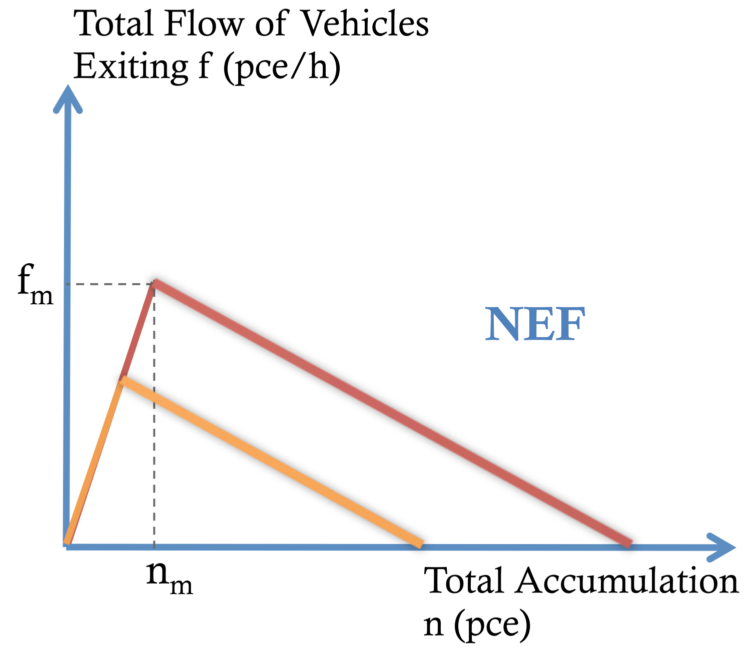
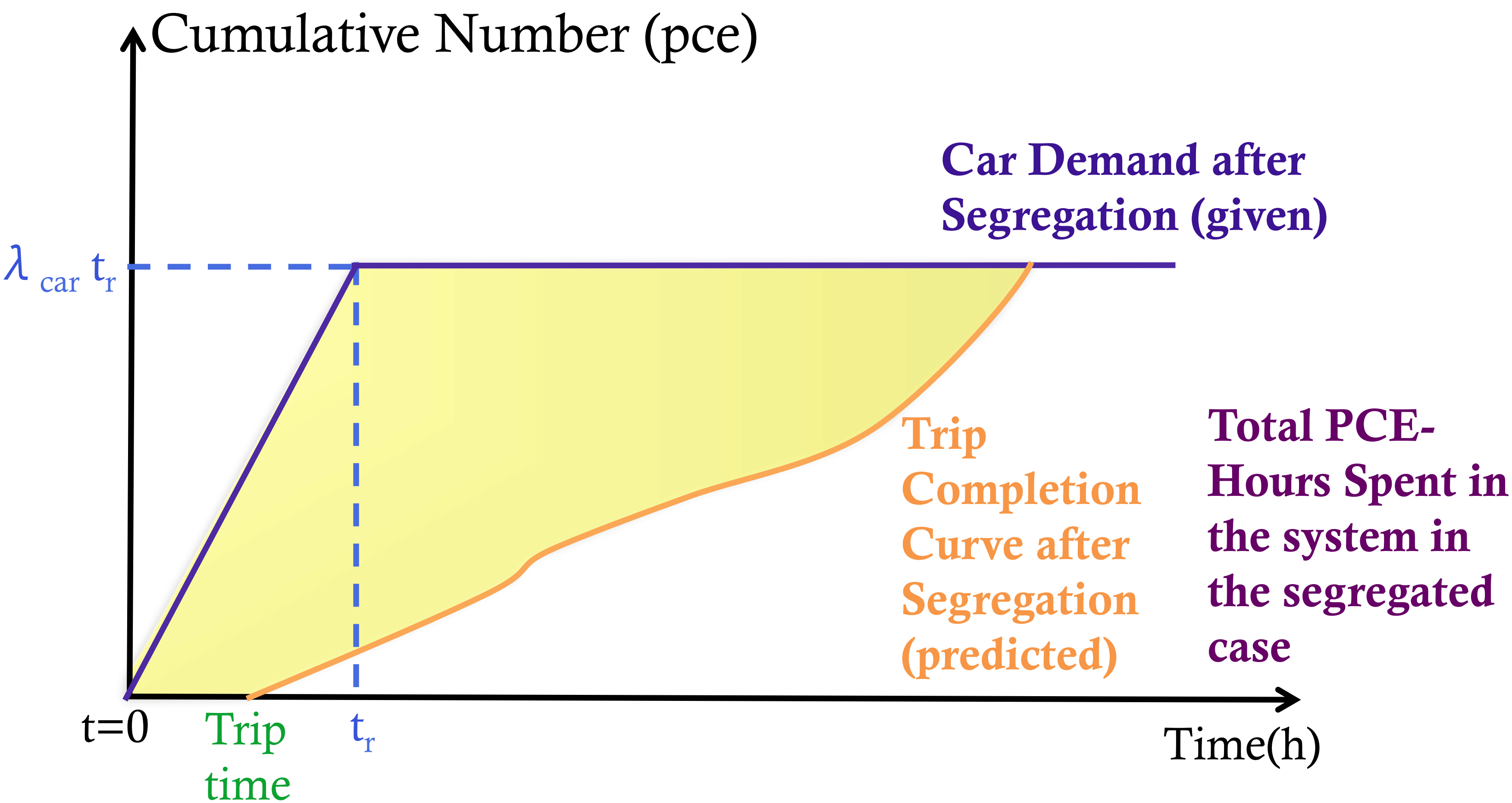


Segregated Case

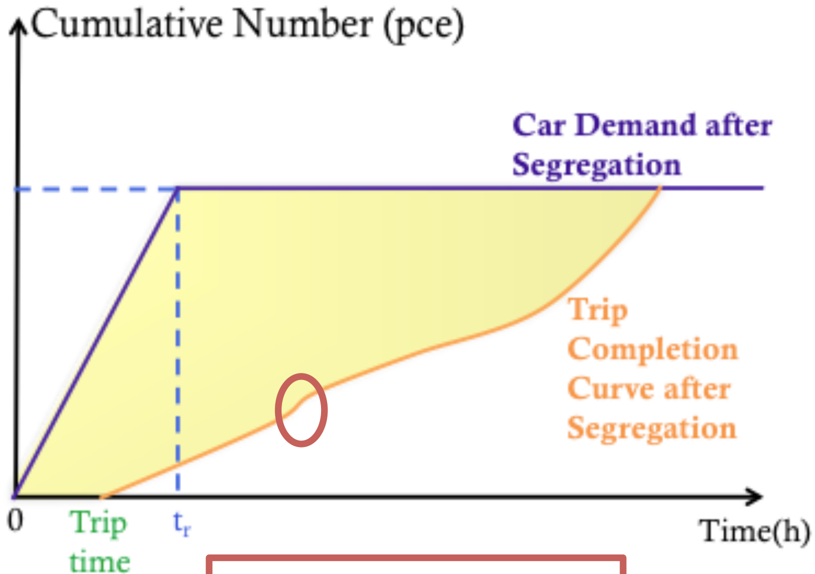
- Use integer number of bus lanes
- Follow similar methodology with rescaled models



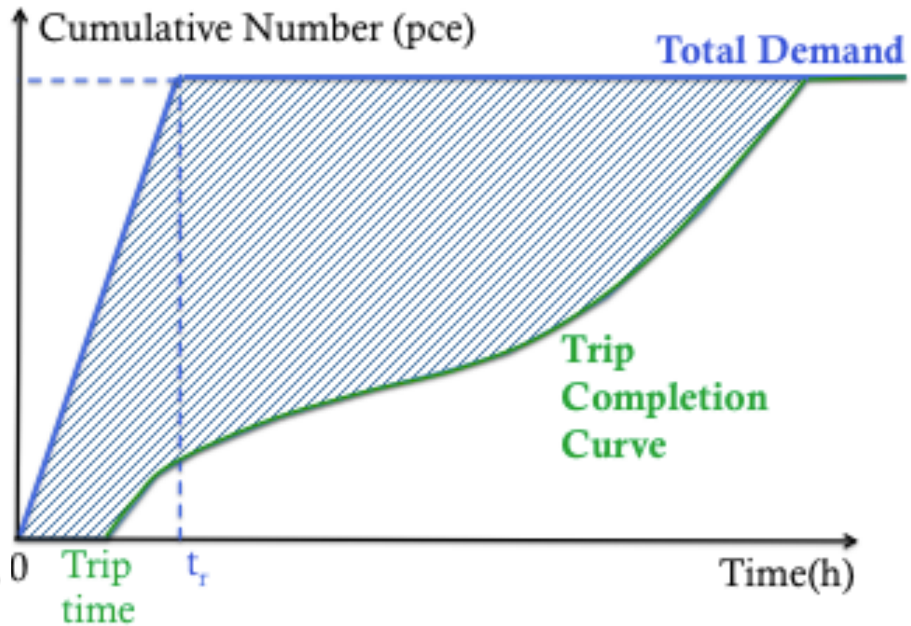
Queuing Diagram: Segregated Case



Compare Segregated and Non-Segregated Case



Heightened Trip Completion Rate



Total Pce-Hours Spent in the system in the segregated case (Cars Only since Bus Delay=0)

Total Pce-Hours Spent in the system in the non-segregated case

Recall Why Benefits Arise:

Buses move faster

Bus lane conversions cause more cars to queue outside the network

Buses complete their tours earlier in the day

During the rush, the car accumulation inside the network is smaller

Cars enjoy a network free of buses early on in the day

Cars confront lower network accumulations

Benefit to Transit Agencies

Transit agencies also benefit from the lane conversions because:

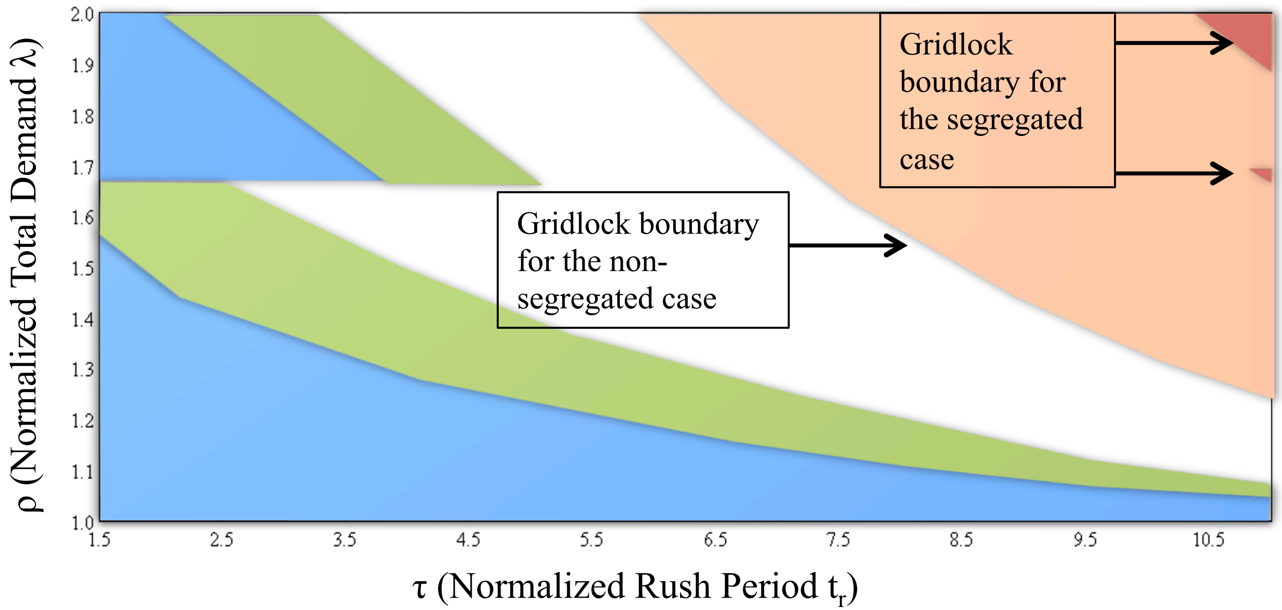
As buses move faster → Buses complete their tours earlier in the day → **Fewer buses are needed to maintain target service frequency**

Numerical Analysis

Parameters for Downtown San Francisco borrowed from (Geroliminis and Daganzo, 2007)

f_m = 15660 pce/h
n_m = 3000 pce
n_c = 9500 pce

Assumed:
Number of lanes = 3
Bus proportion is 20% of λ (pce/h)



Not beneficial in total passenger-hours or car-hours travelled

Beneficial in total passenger-hours but not car-hours travelled

Beneficial in both total passenger-hours and car-hours travelled

On-going Work

- Adapt the model for non-zero demand outside the rush
- Account for different vehicle trip lengths
- Perform a sensitivity analysis of inputs
- Develop a microsimulation as ground truth to test findings

Extending our Work

This work can be extended to carpool lanes and most special use lanes

Thank you