Simulating Traffic

6.336 Introduction to Numerical Simulation

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Traffic Congestion

Macroscopic:
Annual cost of up to **124 Billion** in the US [1]
Unnecessary fuel consumption & environmental damage

Personal Level:
Mental well-being
82 hours stuck in traffic per year [2]

Urban Planning:
Cities need to be able to handle congestion in an efficient way, think evacuation and living

[1] The future economic and environmental costs of gridlock in 2030, Centre for Economics & Business Research , 2014
[2] The Public Health Costs of Traffic Congestion , Harvard Center for Risk Analysis, Jonathan I. Levy, Jonathan J. Buonocore, & Katherine von Stackelberg, 2010

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Key Question

How does traffic behave during peak hours?

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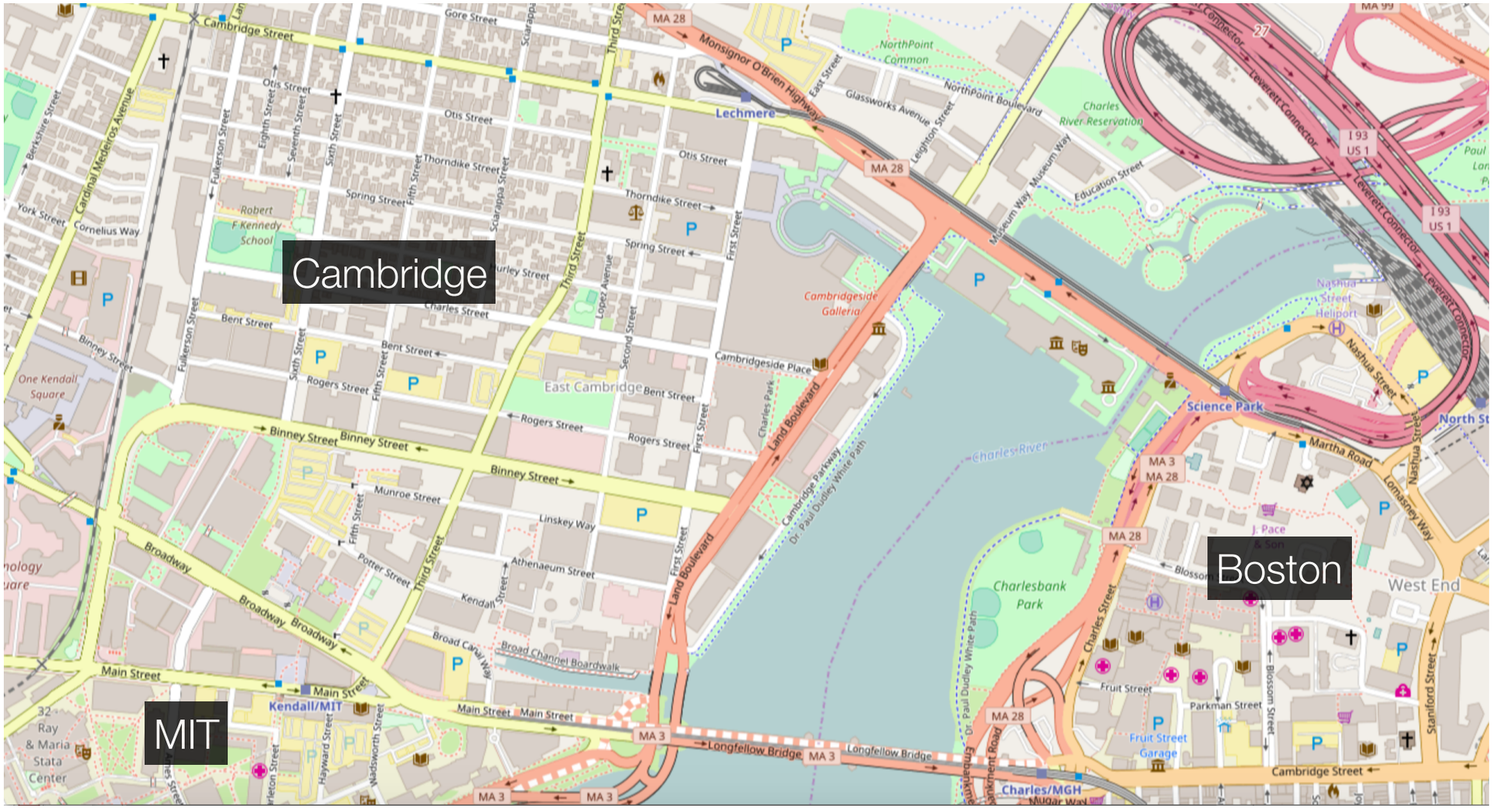
Project Scope



Area selected has a good representation of features in founds in urban areas

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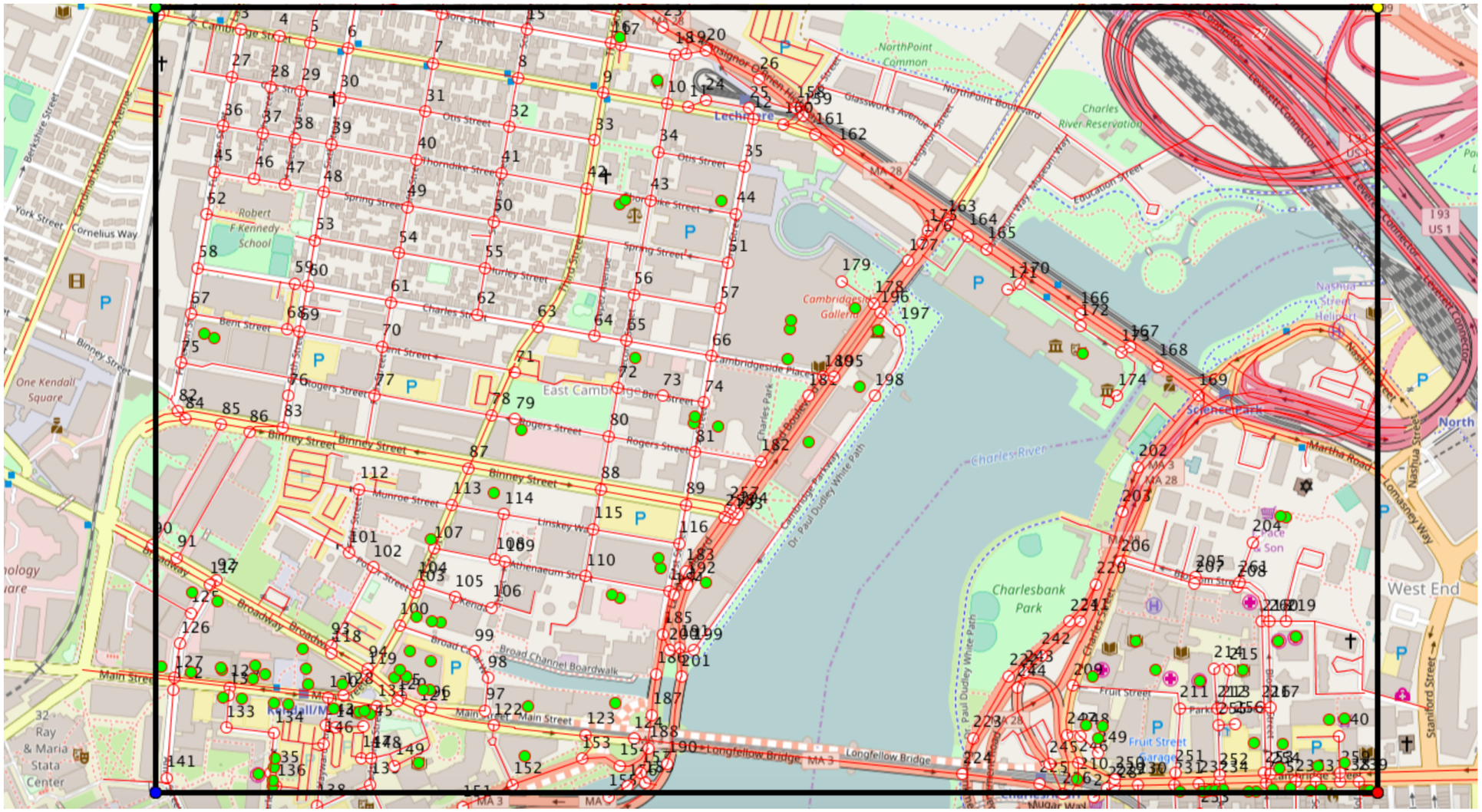
Project Scope



261 **Nodes**

350 **Edges**

Data obtained from **OpenStreetMap**

OD matrix generated from **United States Census, American Community Survey**

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Problem Formulation

Nodes Travel time (s)

Edges Flow rate of cars (vehicles/s)

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Constitutive Equation

Bureau of Public Roads (BPR) Function

$$T_i - T_j = T_{ij,0}(1 + 0.15(\frac{f_{ij}}{k_{ij}})^4)$$

Nodes Travel time (s)

Edges Flow rate of cars (vehicles/s)

"A Circuit Simulation technique for Congested Network Traffic Assignment", Cho,H.J. & Huang,H. AIP Conference Proceedings, 963, 993 (2007)

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Constitutive Equation

Bureau of Public Roads (BPR) Function

$$T_i - T_j = T_{ij,0}(1 + 0.15(\frac{f_{ij}}{k_{ij}})^4)$$

Free flow travel time

Nodes Travel time (s)

Edges Flow rate of cars (vehicles/s)

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Constitutive Equation

Bureau of Public Roads (BPR) Function

$$T_i - T_j = T_{ij,0}(1 + 0.15(\frac{f_{ij}}{k_{ij}})^4)$$

Free flow travel time

Capacity of road

Nodes Travel time (s)

Edges Flow rate of cars (vehicles/s)

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Constitutive Equation

Bureau of Public Roads (BPR) Function

$$T_i - T_j = T_{ij,0}\left(1 + 0.15\left(\frac{f_{ij}}{k_{ij}}\right)^4\right)$$

Gives the ratio between free-flow travel time and actual travel time

Nodes Travel time (s)

Edges Flow rate of cars (vehicles/s)

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Constitutive Equation

Modifying the equation for network use:

$$T_i - T_j = T_{ij,0}(1 + 0.15(\frac{f_{ij}}{k_{ij}})^4) \ \ sign(f_{ij})$$

Nodes Travel time (s)

Edges Flow rate of cars (vehicles/s)

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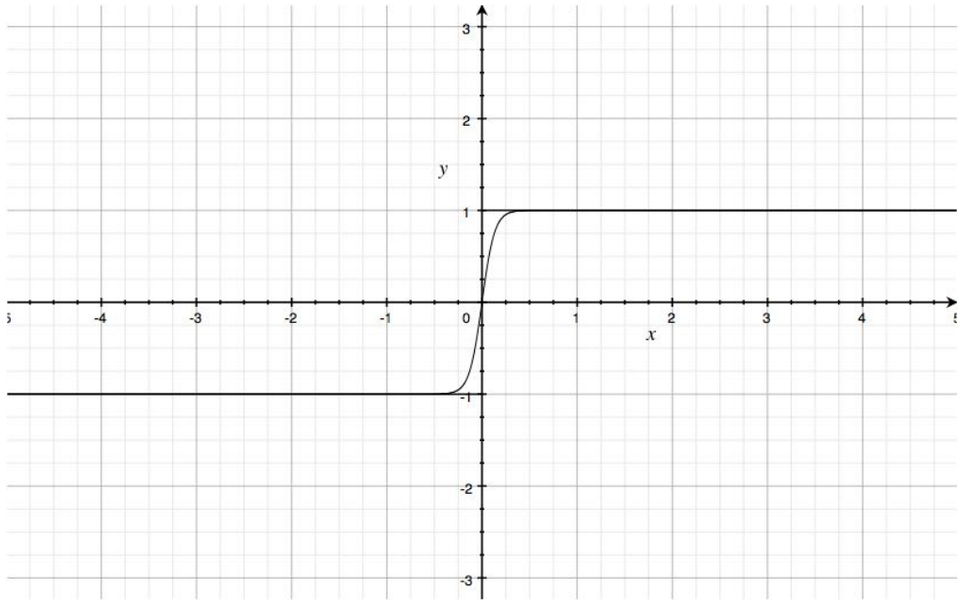
Constitutive Equation

Modifying the equation for network use:

$$T_i - T_j = T_{ij,0}(1 + 0.15(\frac{f_{ij}}{k_{ij}})^4) \;\; 2(\frac{1}{1 + e^{-wf_{ij}}} - 0.5)$$



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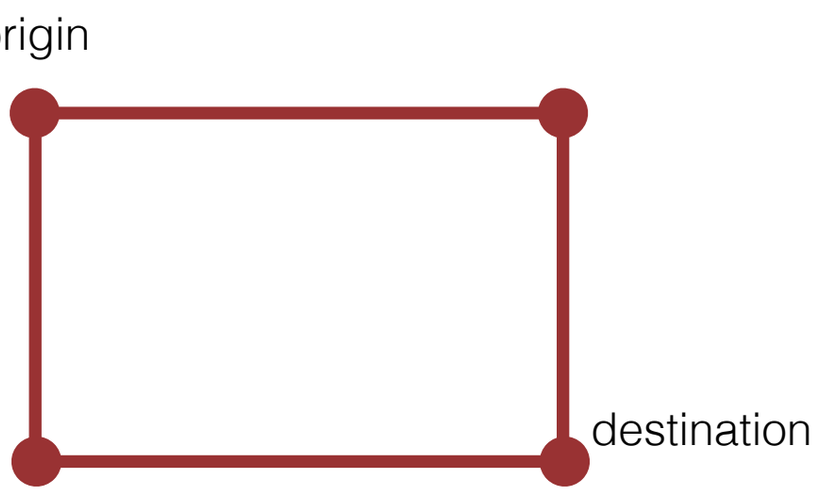
Inputs

We add a flow source at the origin and a sink at the destination(s)



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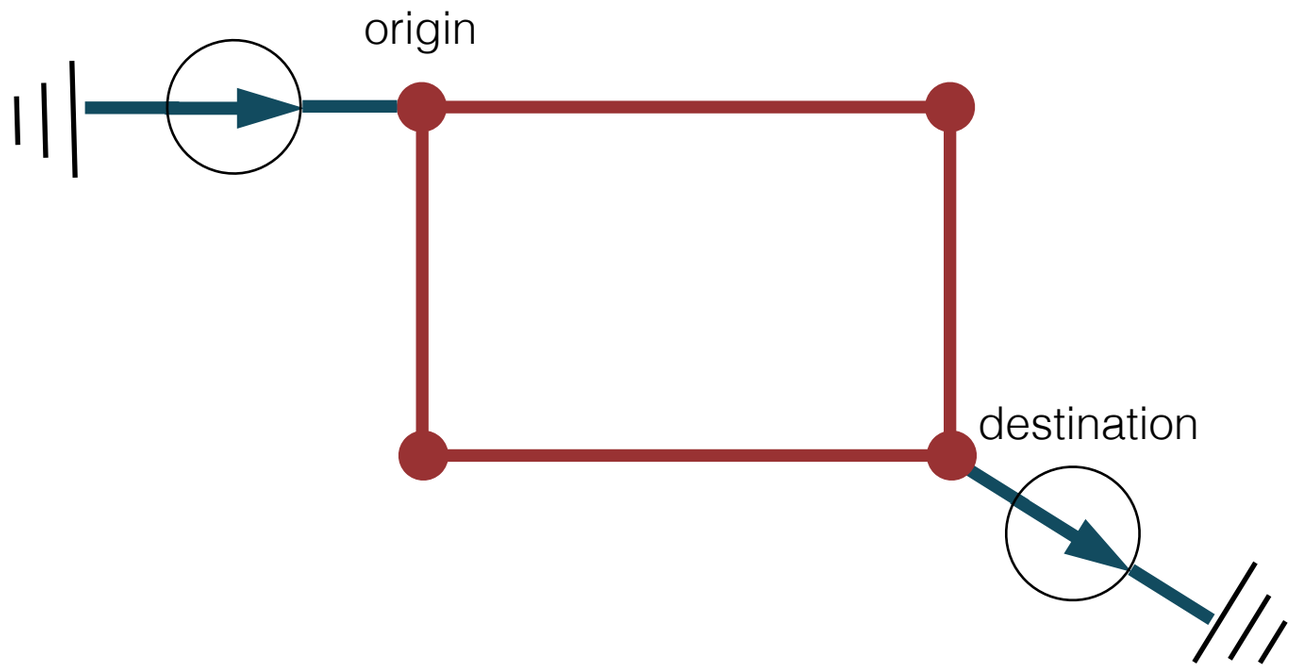

TrafficBehavior am

- People travel from residential zone into various locations in the city for work
- Points of interest have different operation hours

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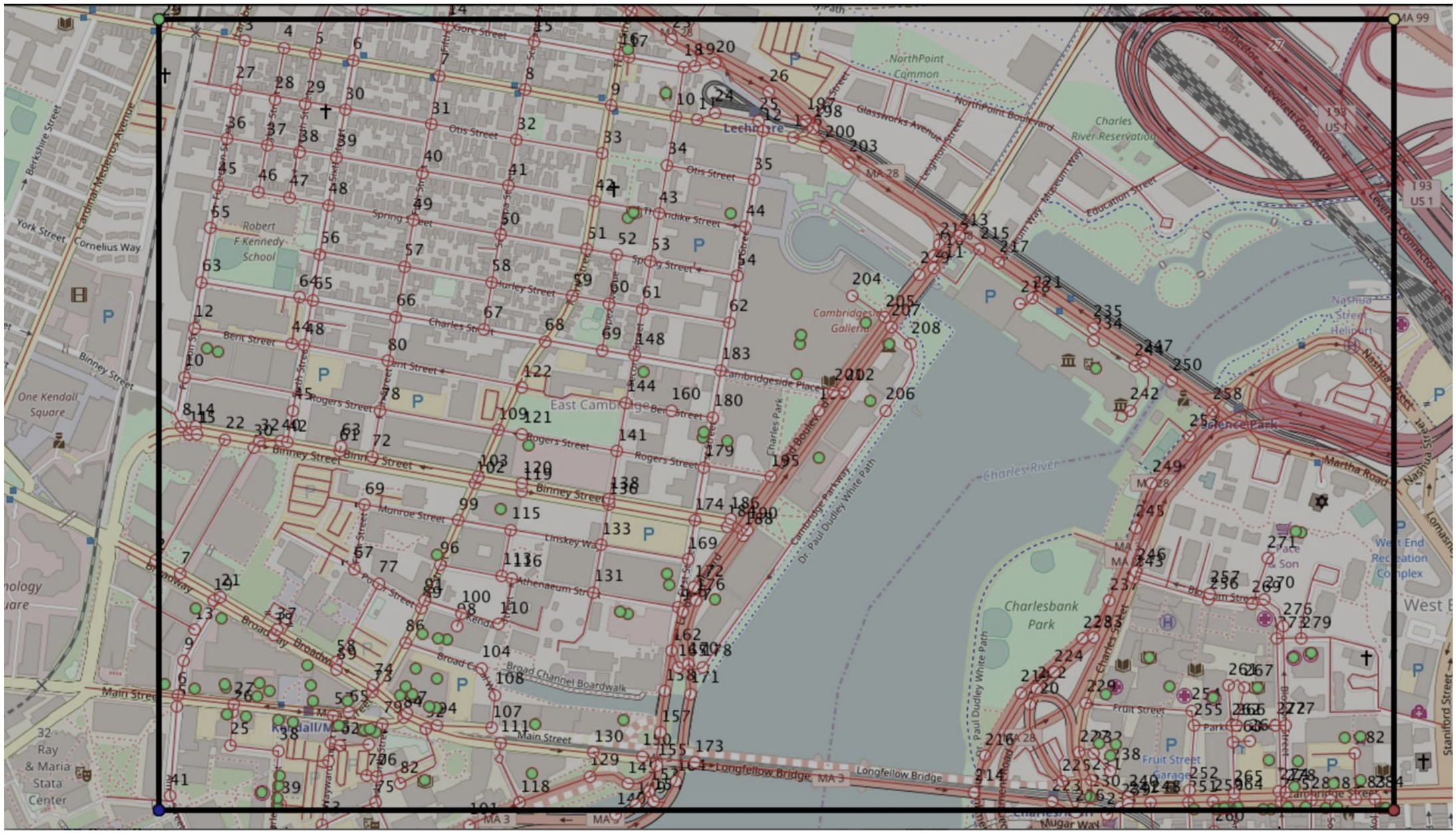
TrafficBehavior am



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TrafficBehavior **7** am

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TrafficBehavior **9**am

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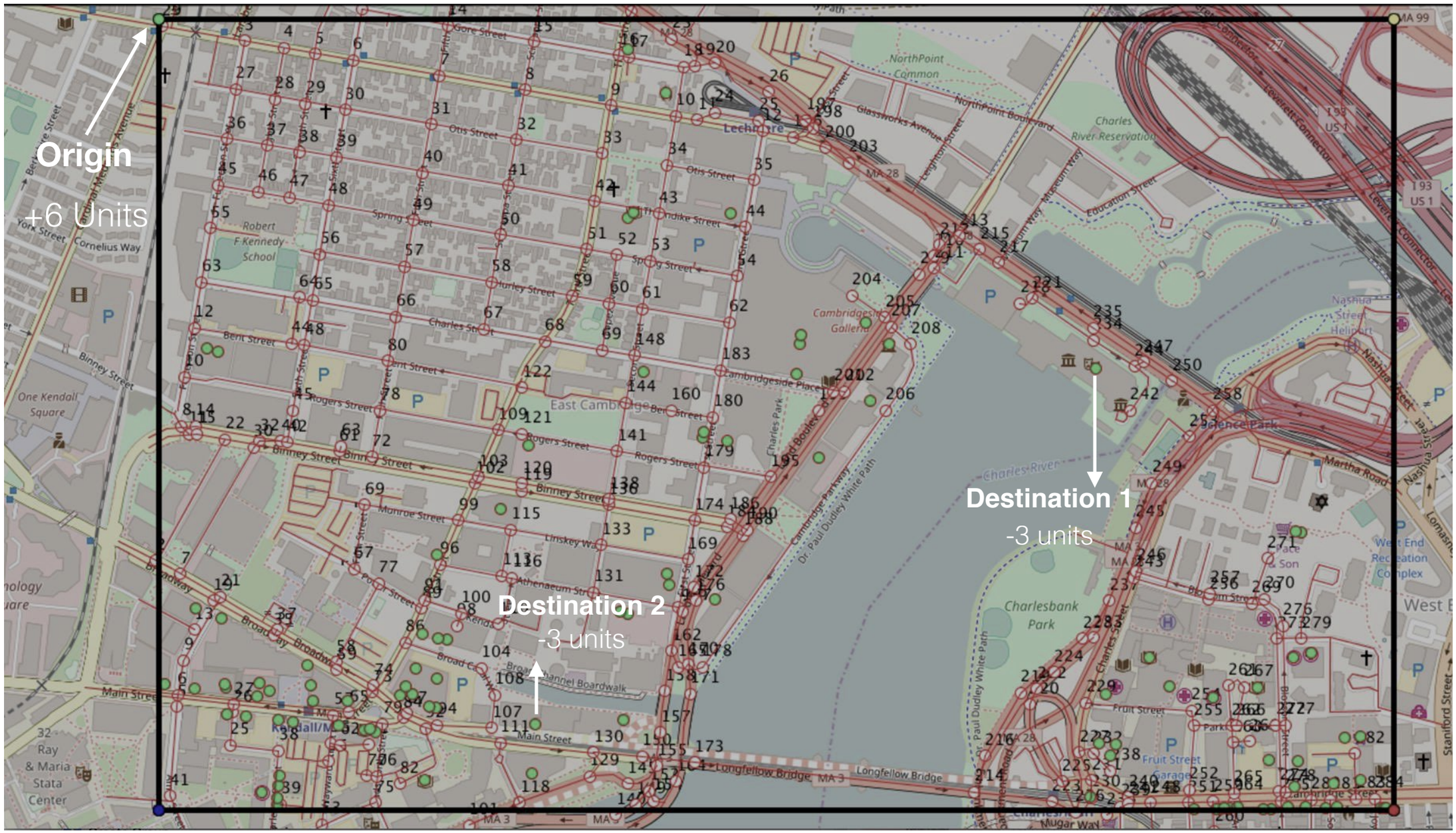
TrafficBehavior**11**am



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7 am

9 am

11 am

Steady-state analysis

Node-Branch Formulation
Regular Newton Method
3 sets of flow sources

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TrafficBehavior$_{pm}$

What happens when people start leaving work for home?

- **Dynamic Analysis**
- Forward Euler Method
- Multiple origins & Single Destination

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TrafficBehavior$_{\text{pm}}$

$$\frac{dT_i}{dt} = -k \sum_{j \in V(i)} f_{ij} + u_i(t)$$

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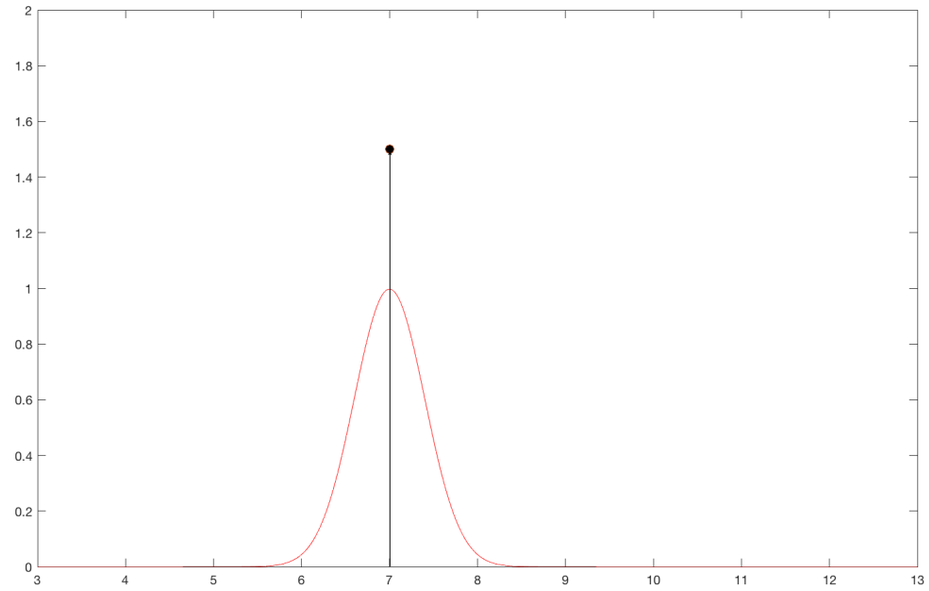
TrafficBehavior_pm

- Input Gaussian Smoothing



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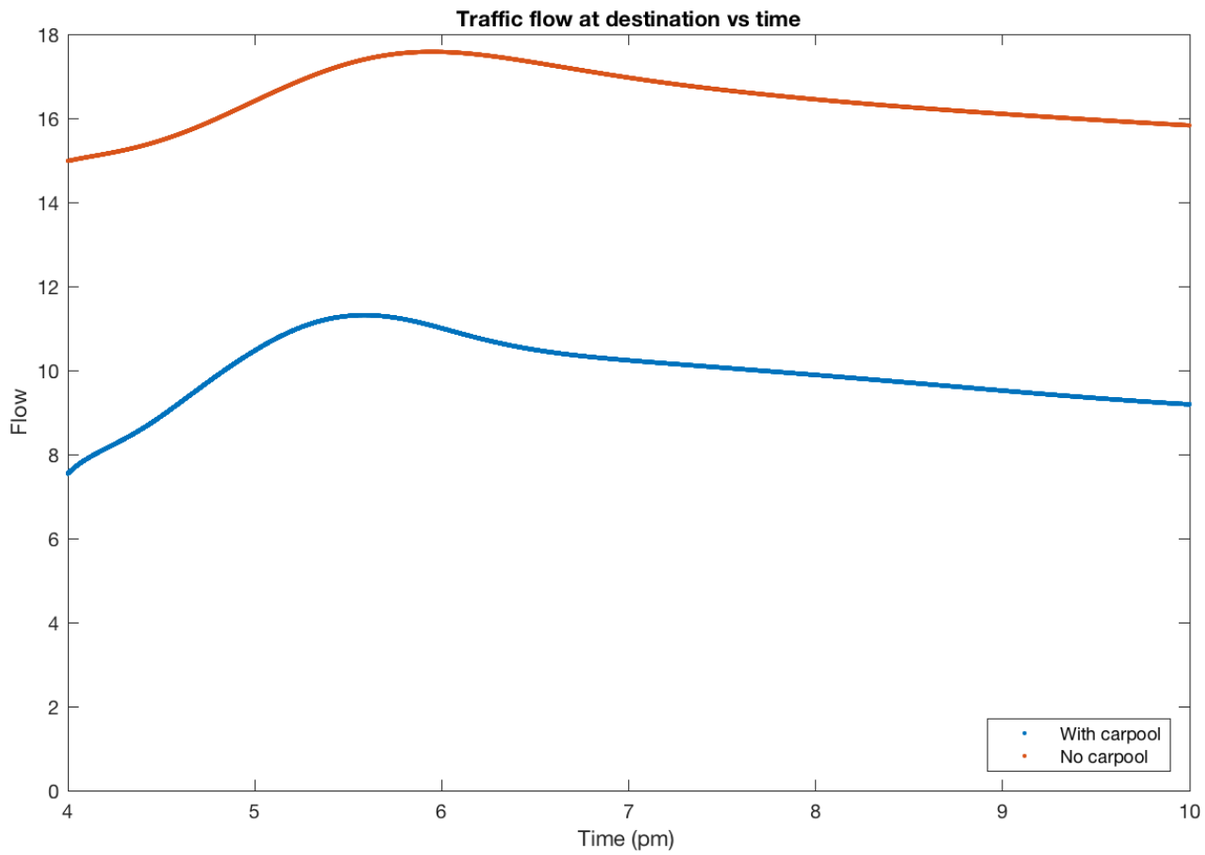
TrafficBehavior$_{pm}$

- Carpooling reduces the flow of at the destination
- Peak of the traffic at is at 5:30 with carpooling, 6:00 without



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Applications

Wait...doesn't Google Maps do this?

- Yes, we can get real time update of traffic conditions using google maps...
- But simulation allows us to evaluate the results of different, **expensive** urban planning decisions and see how different income brackets are affected.

Applications

Examples:

Where should I locate a new hospital?

What is the optimal time to close off a road for repairs?

How useful are policies that distribute road demand throughout the day?

How can we better plan transit routes?

Can employers better stagger shifts to improve business and commutes?

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Applications

How useful are policies that distribute road demand throughout the day?

- Distribute demand evenly across 7-11 am
- Steady-state analysis

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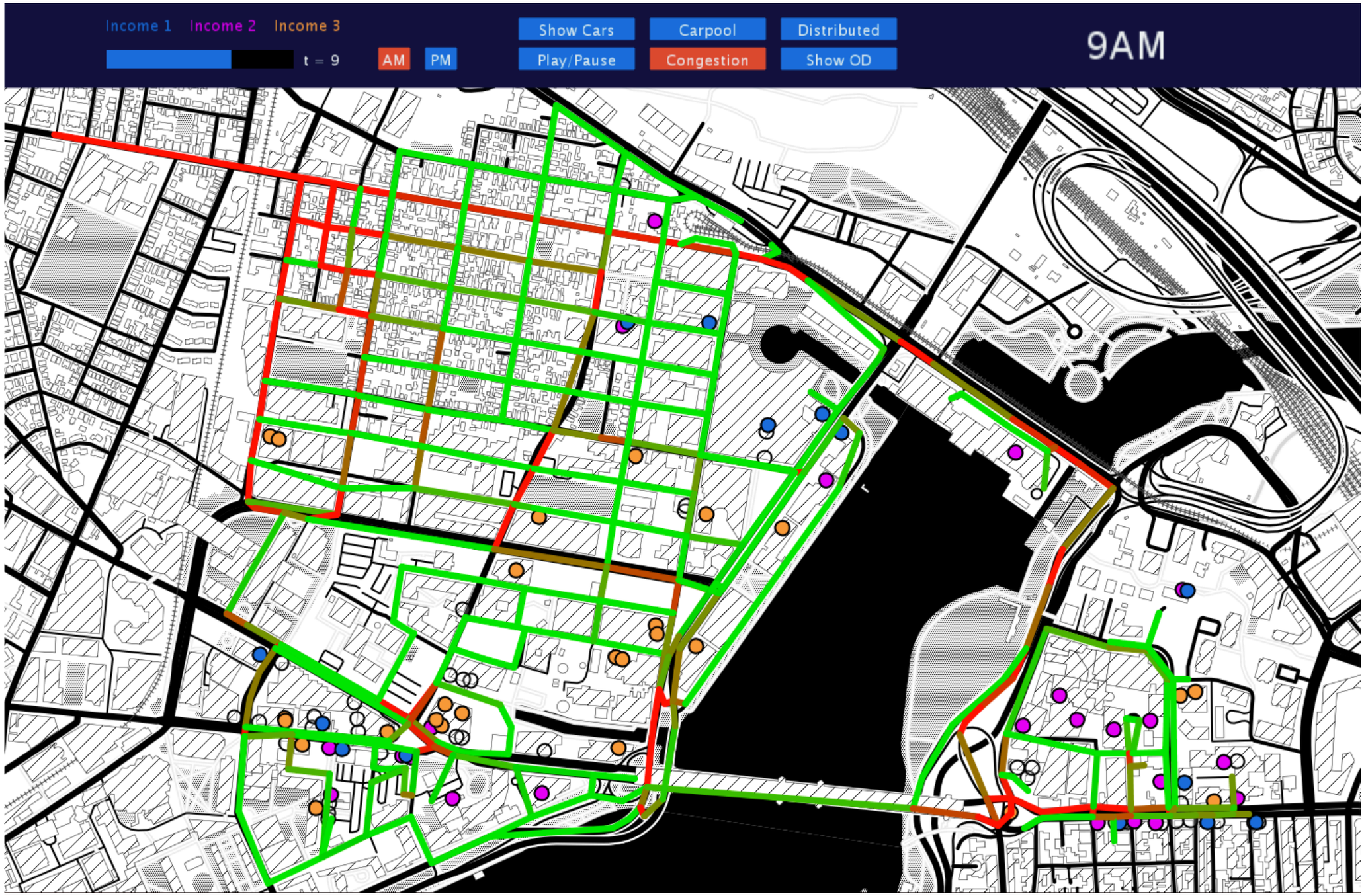
Conclusion

- Carpooling is an effective measure for 9am traffic



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Conclusion

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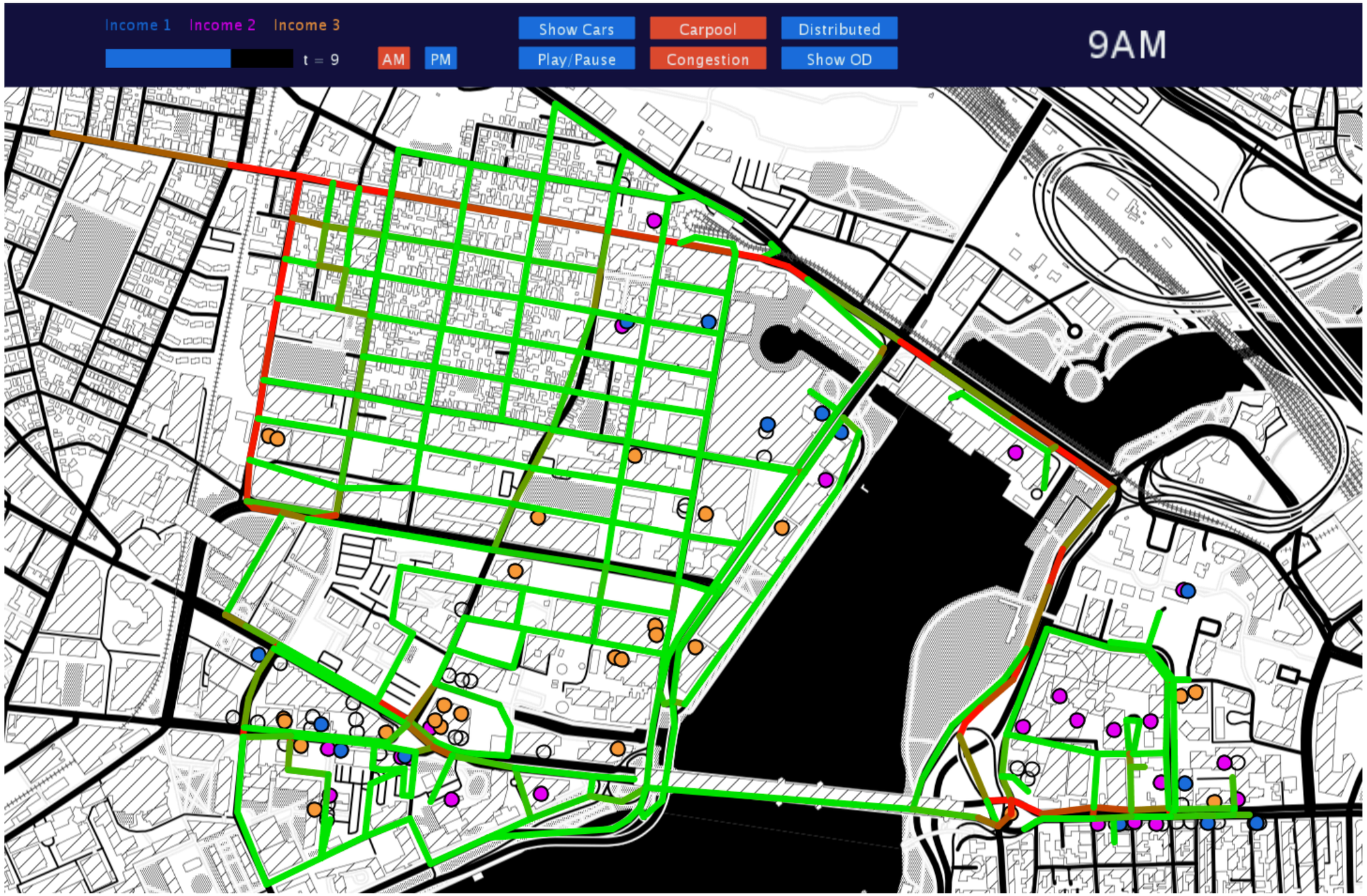

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Conclusion

Figure 1: 9am, No Carpool

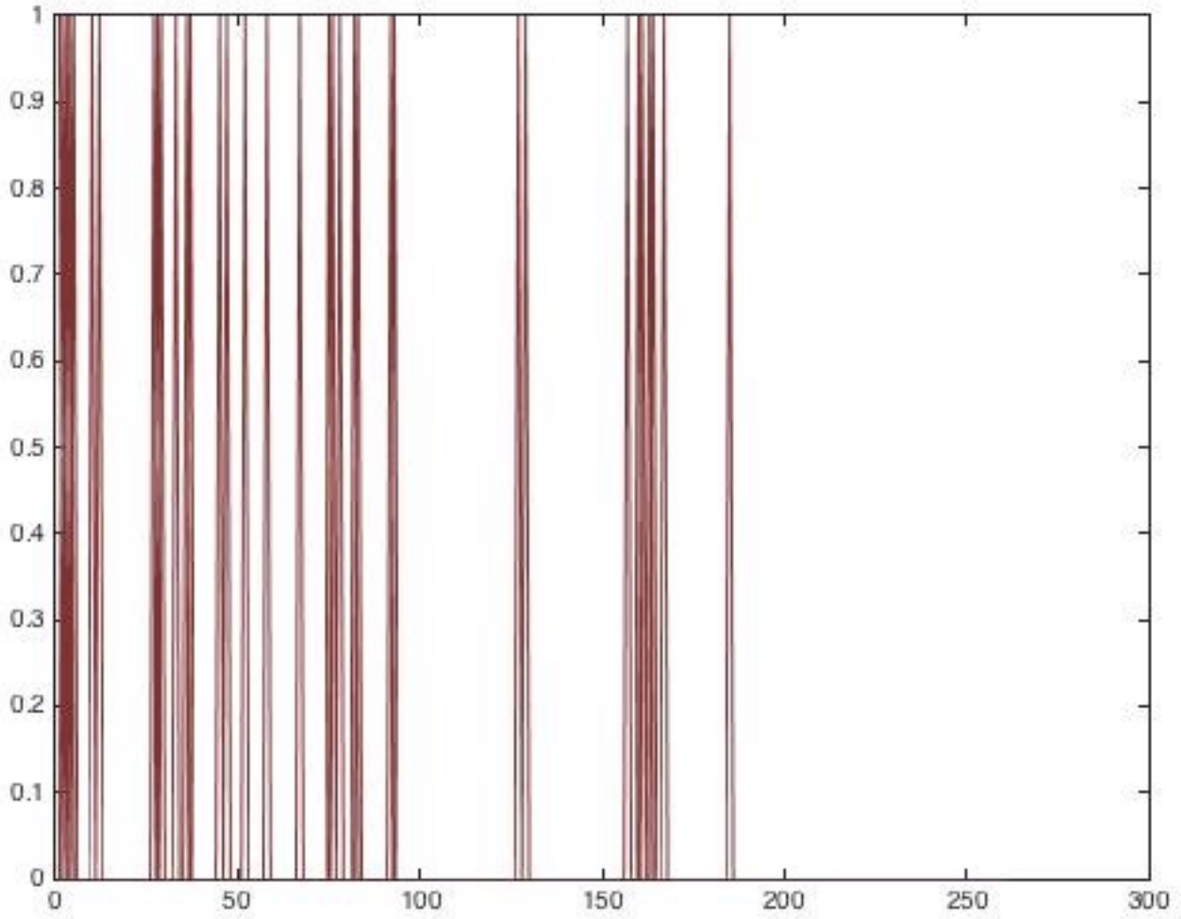
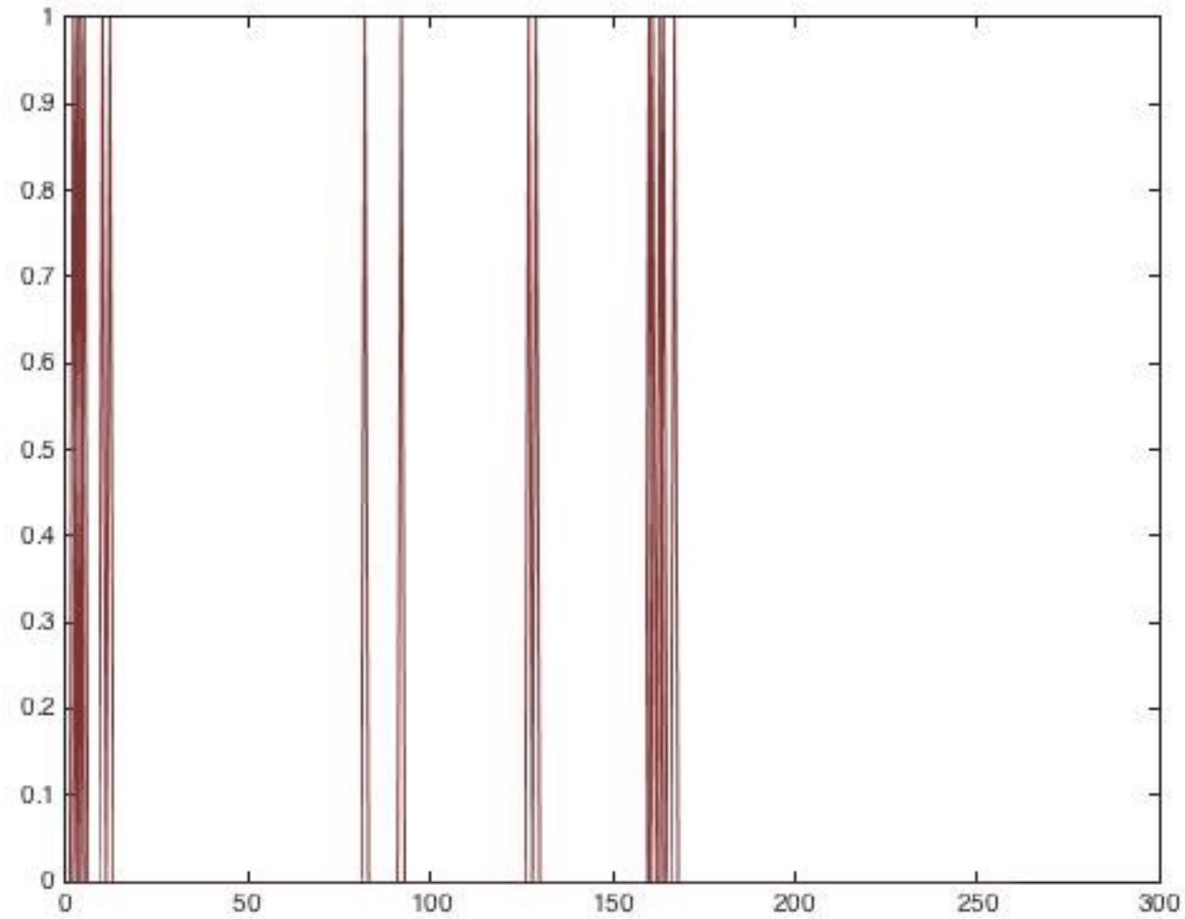


Figure 2: 9am, Carpool



Traffic congestion in urban areas is often a utilization problem , rather than an infrastructure issue.

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Thank you!

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References

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