

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



Key Question

How does traffic behave during peak hours?

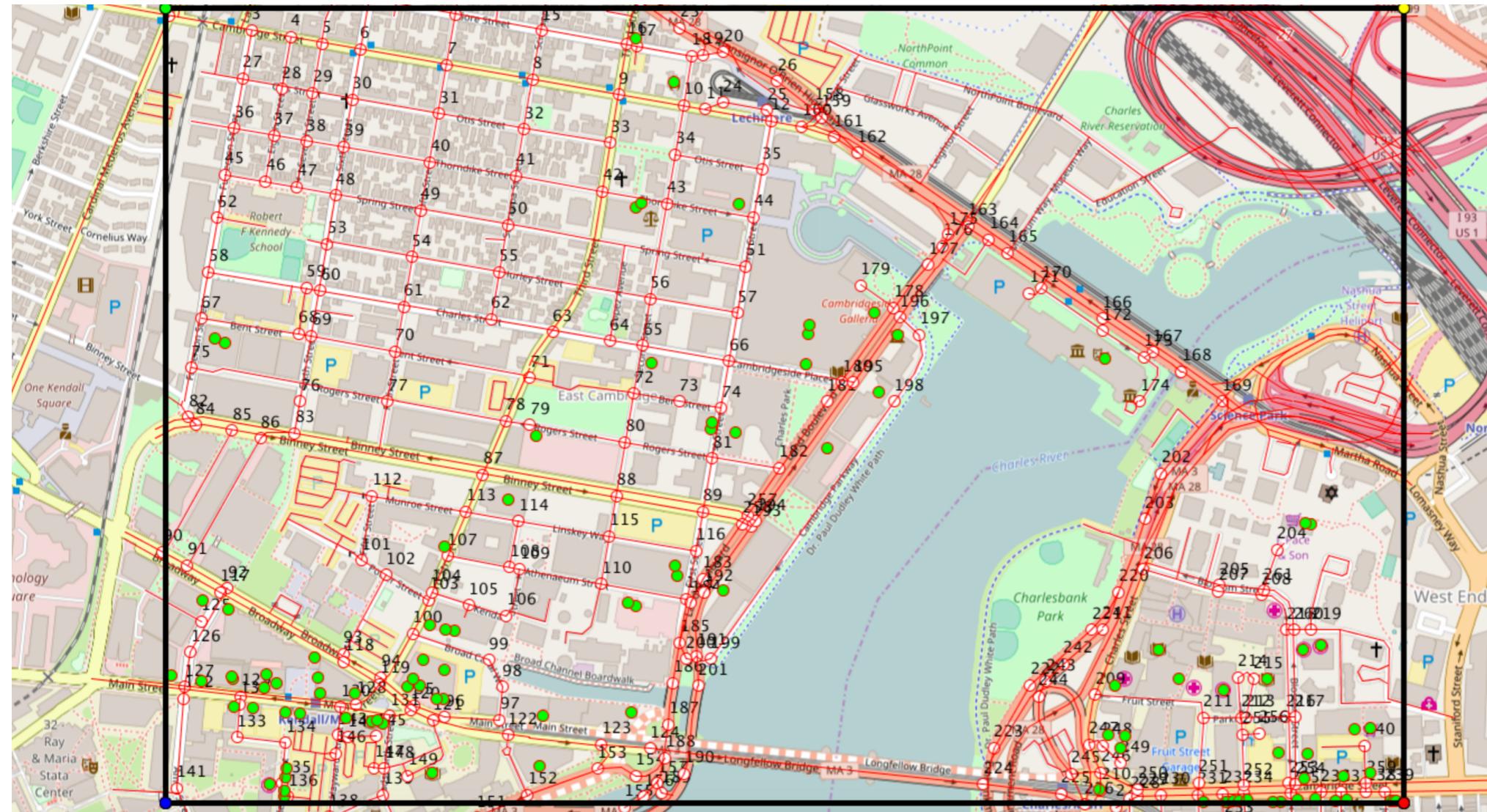


Project Scope



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

Project Scope



Data obtained from **OpenStreetMap**

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

Problem Formulation



Nodes Travel time (s)

Edges Flow rate of cars (vehicles/s)

Constitutive Equation

Bureau of Public Roads (BPR) Function

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



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

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↑
Free flow travel time



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↑
Free flow travel time ↑
Capacity of road



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



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Constitutive Equation

Modifying the equation for network use:

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



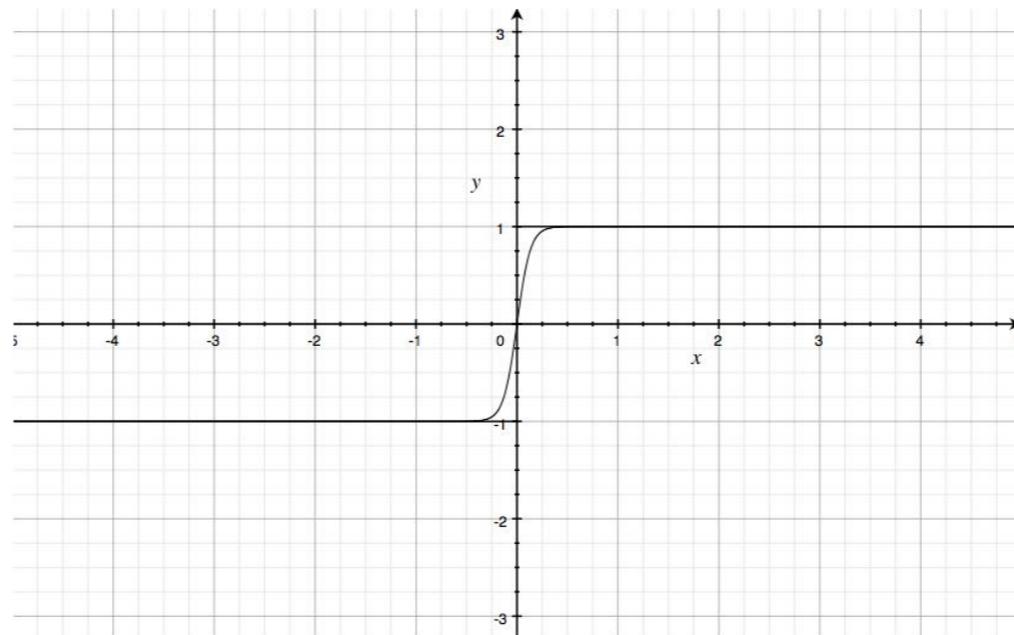
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Constitutive Equation

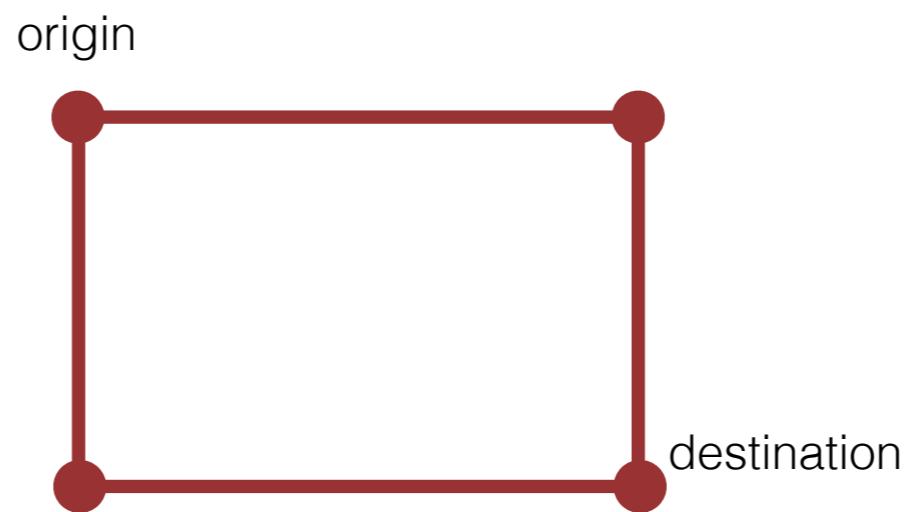
Modifying the equation for network use:

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



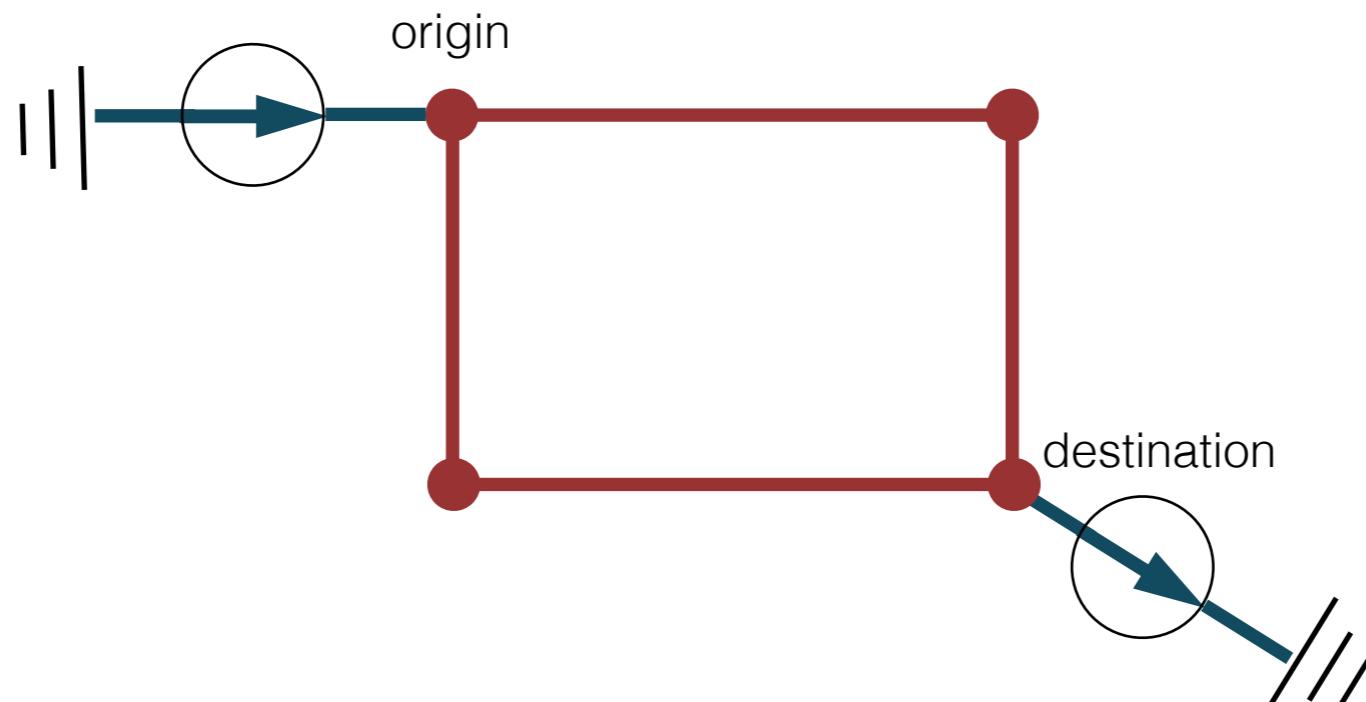
Inputs

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



TrafficBehavior_{am}



Traffic Behavior 7am

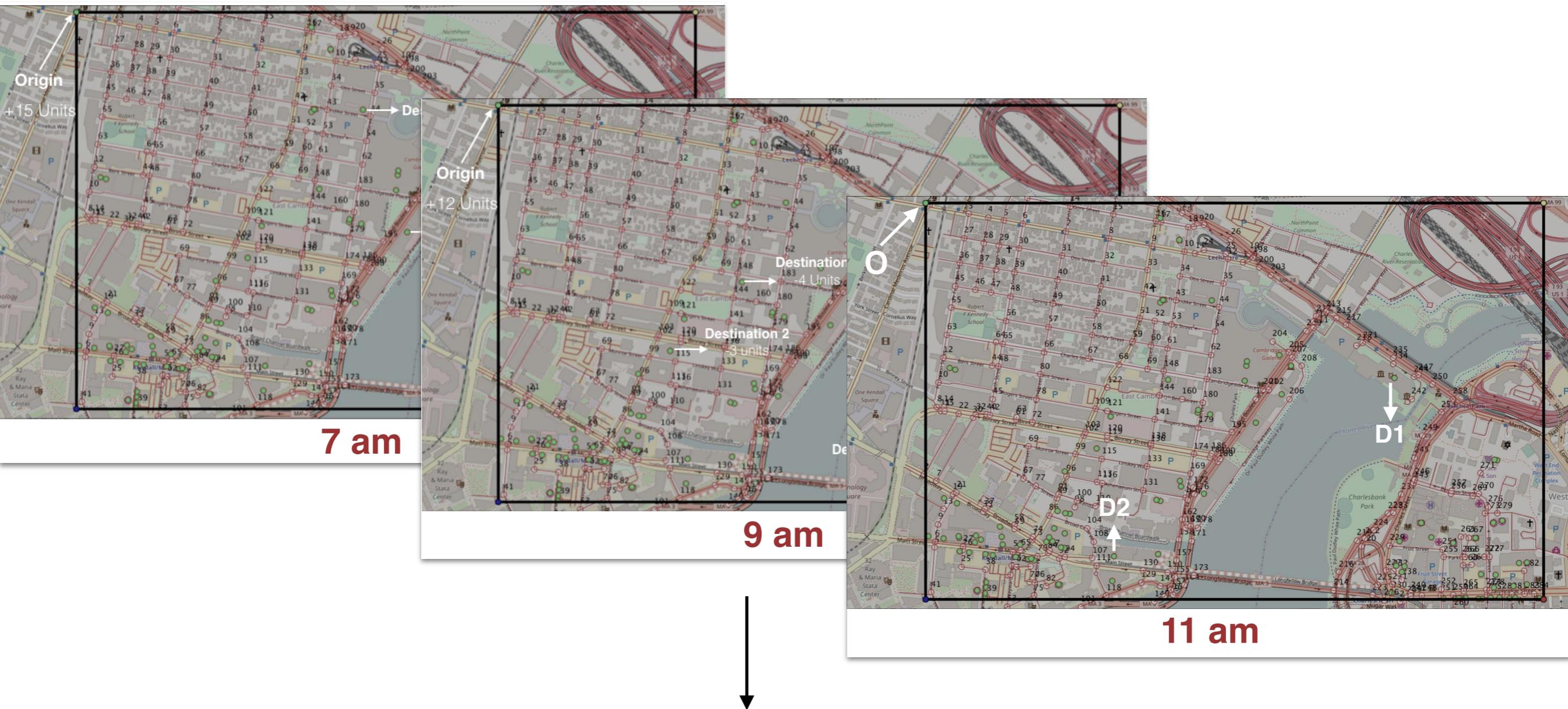


Traffic Behavior 9am



Traffic Behavior 11am





Steady-state analysis

Node-Branch Formulation

Regular Newton Method

3 sets of flow sources



TrafficBehavior^{pm}

What happens when people start leaving work for home?

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



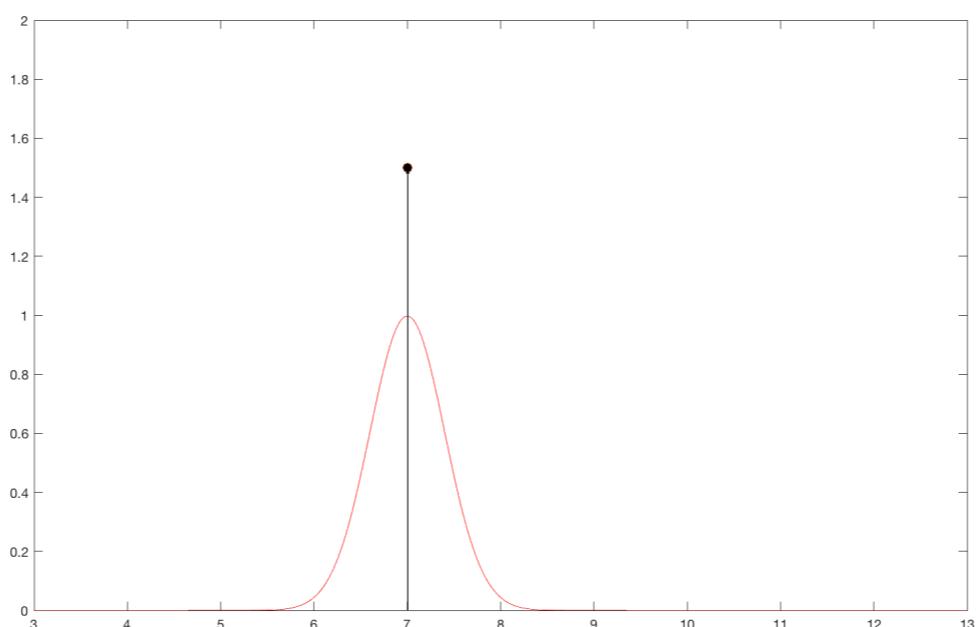
TrafficBehavior_{pm}

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



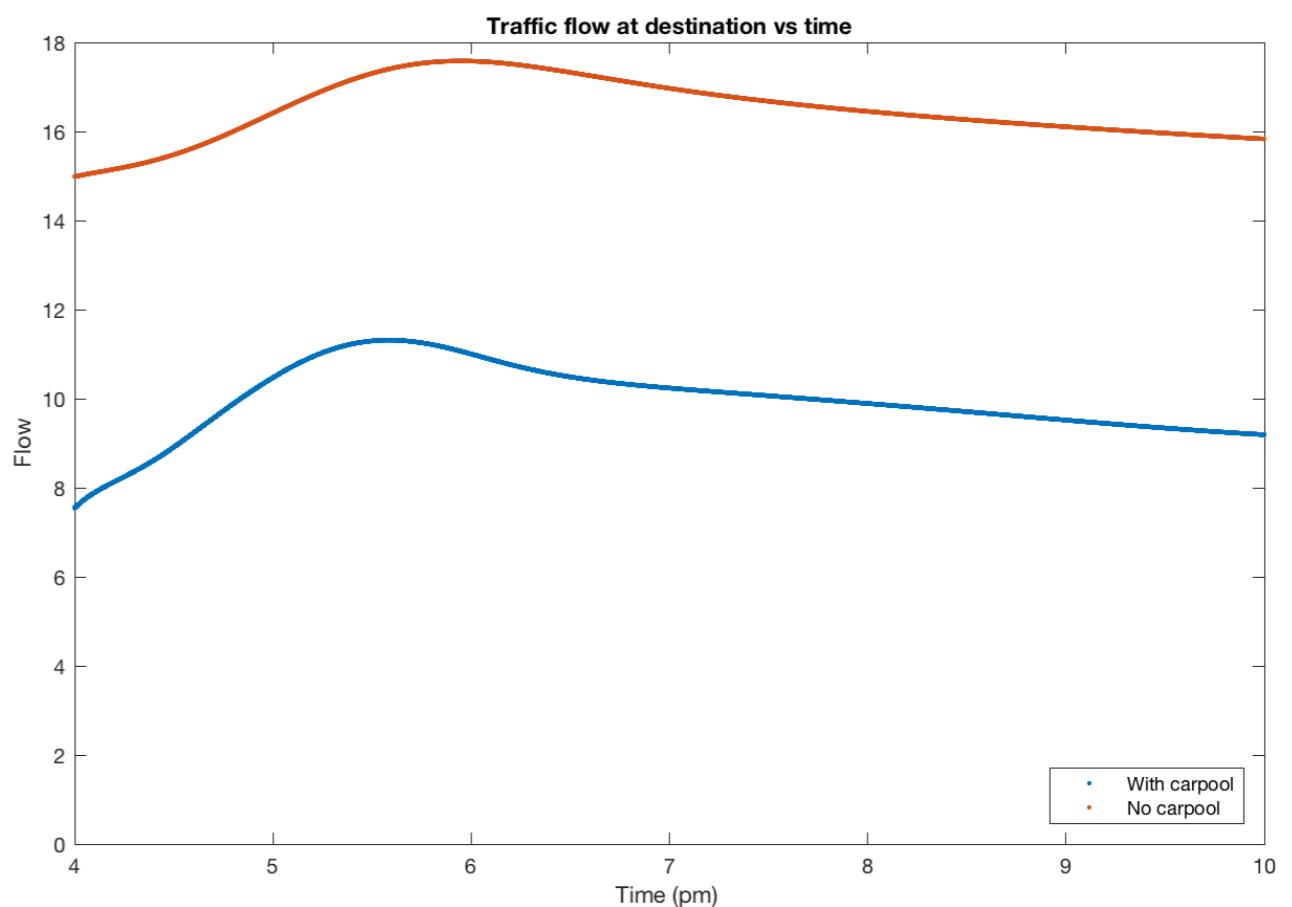
TrafficBehavior_{pm}

- Input Gaussian Smoothing



Traffic Behavior pm

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



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?



Applications

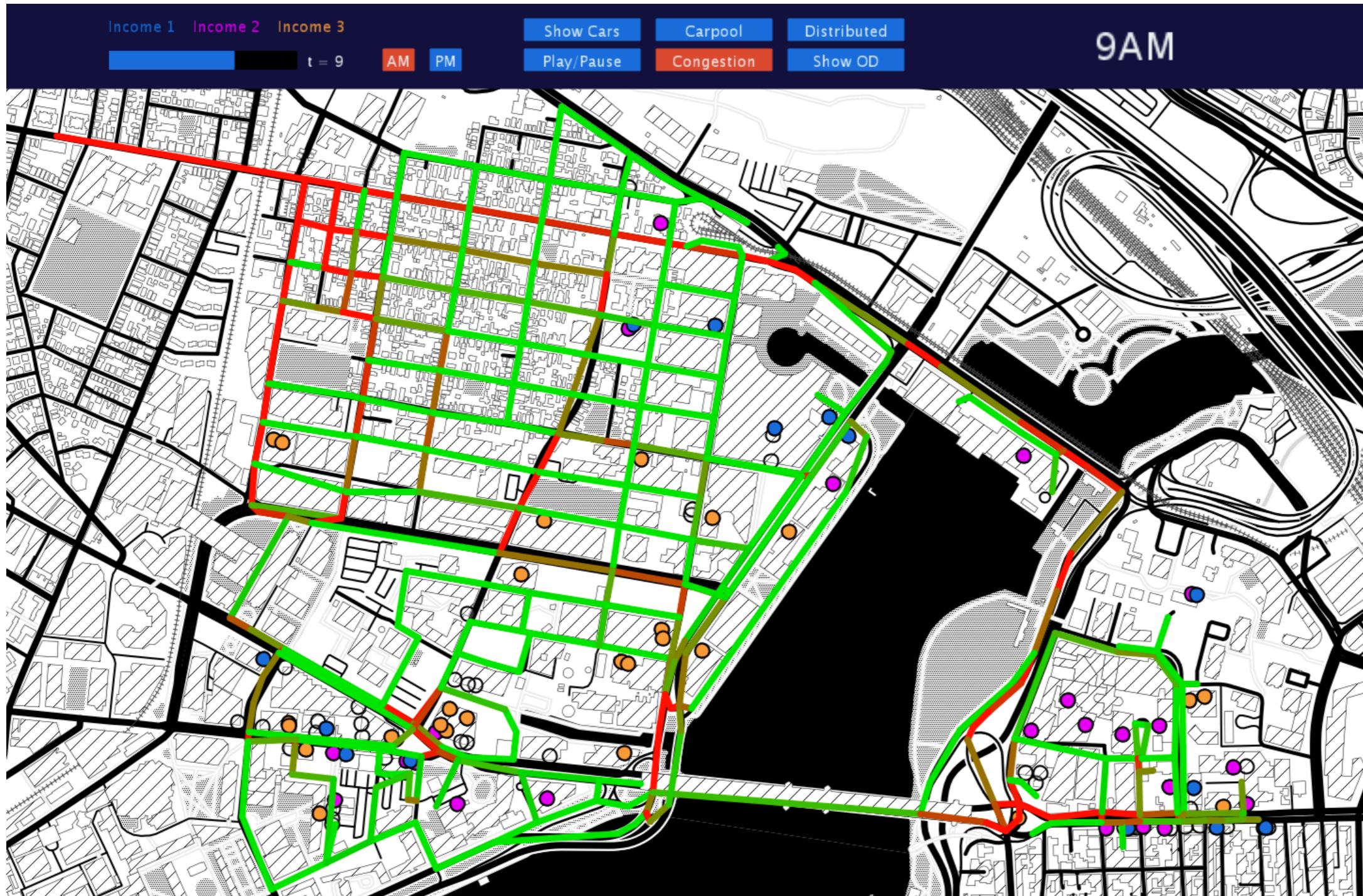
How useful are policies that distribute road demand throughout the day?

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



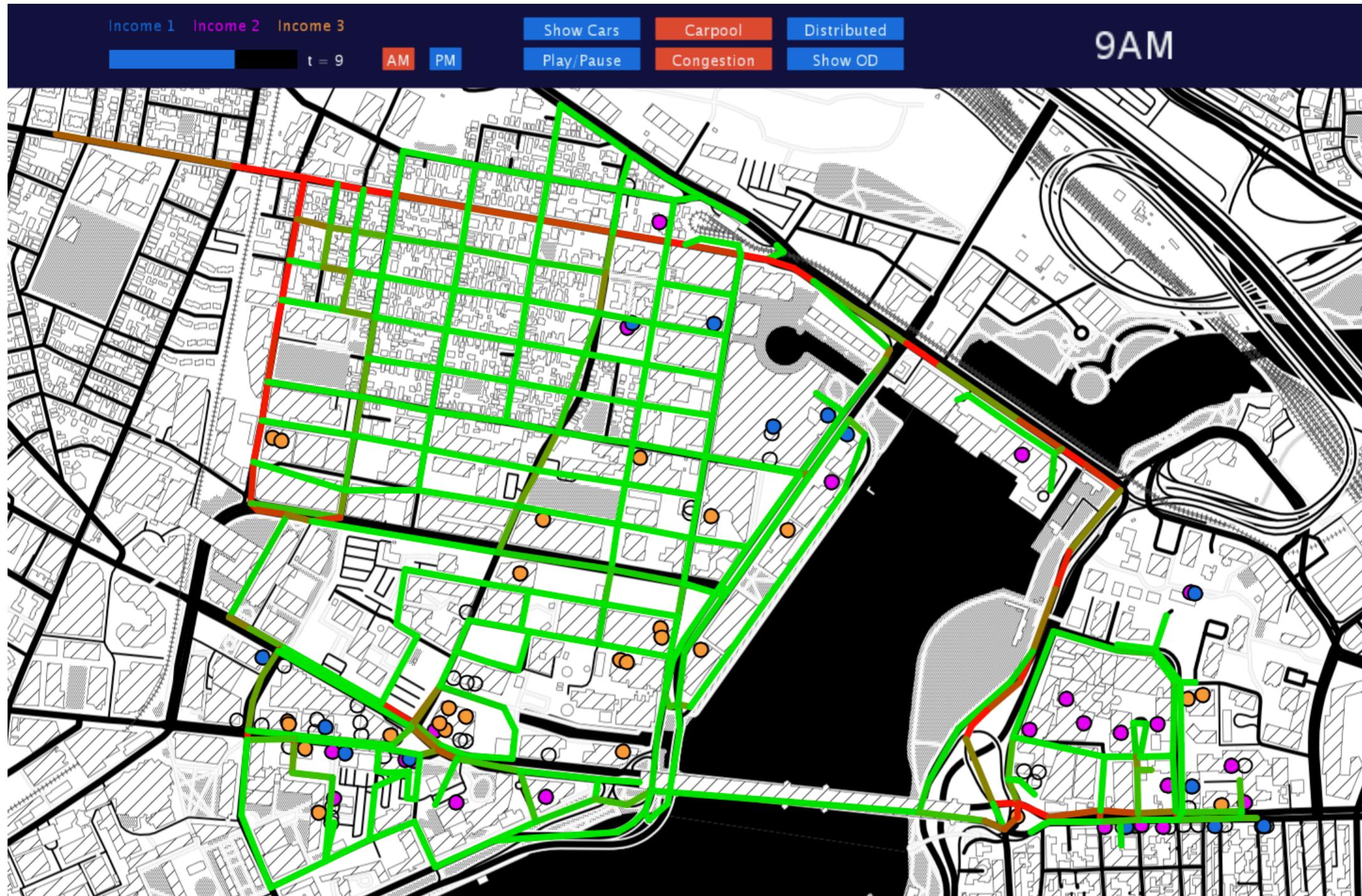
Conclusion

- Carpooling is an effective measure for 9am traffic



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Conclusion

Figure 1: 9am, No Carpool

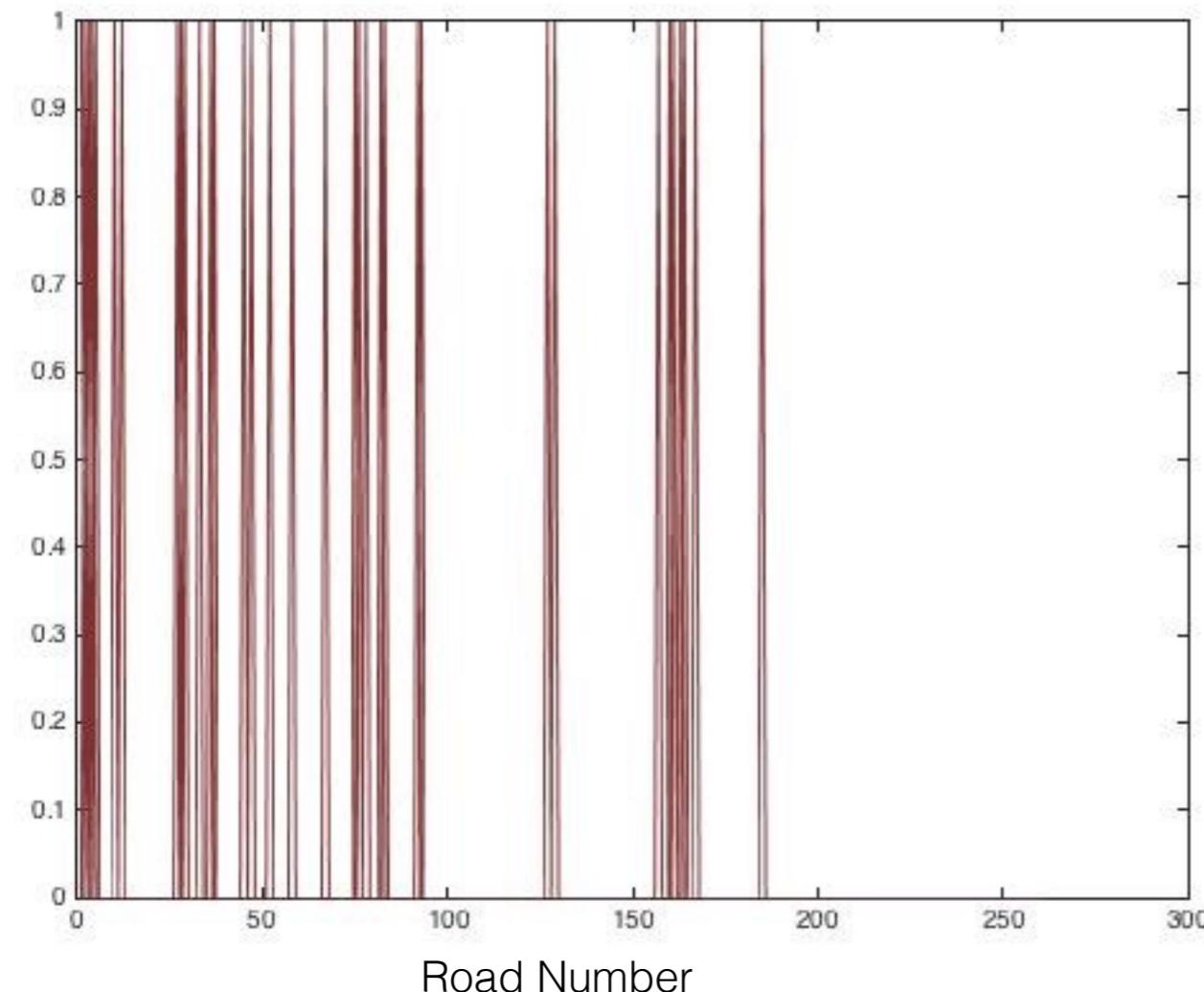
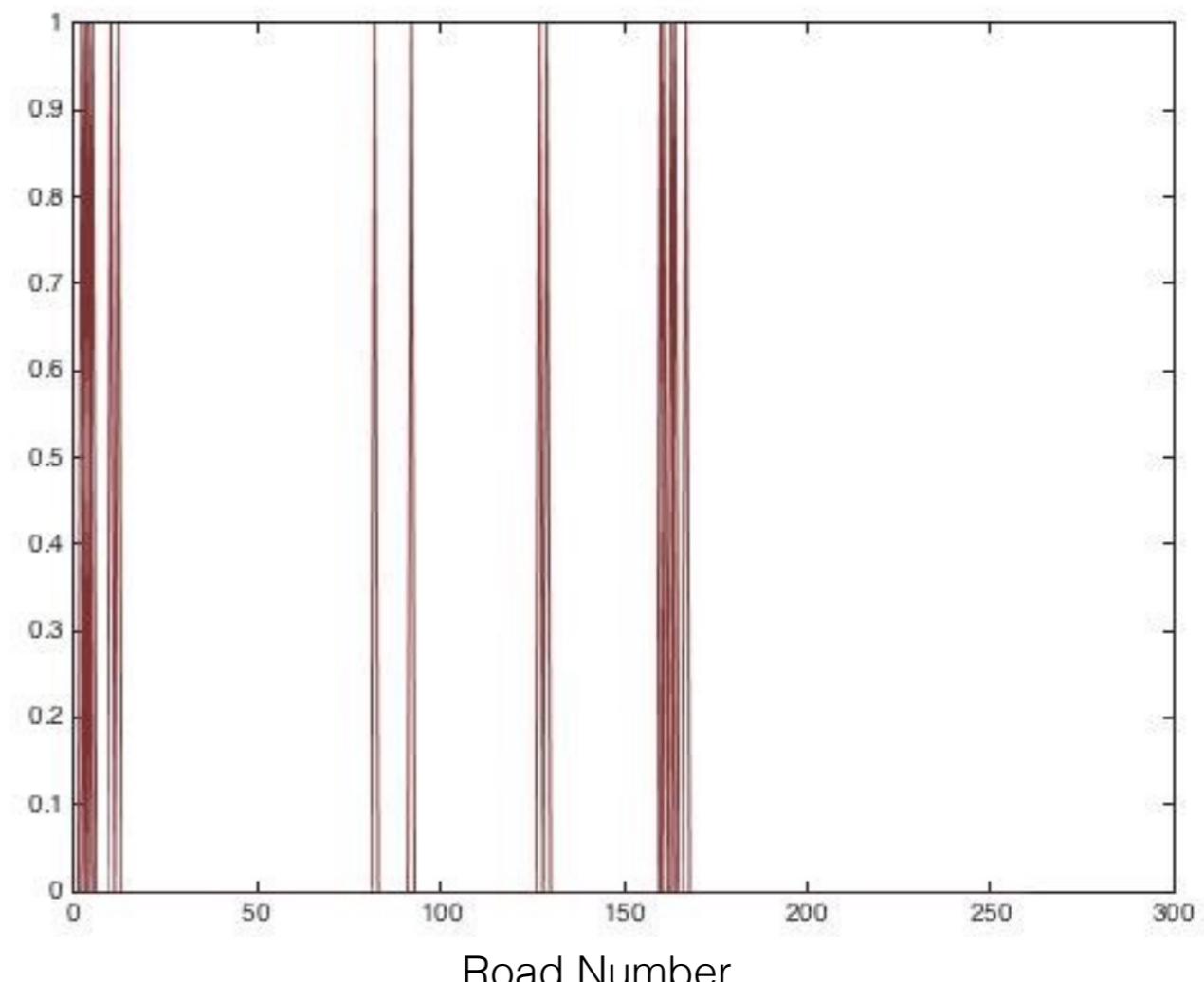


Figure 2: 9am, Carpool



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

Thank you!



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References

- “A Circuit Simulation technique for Congested Network Traffic Assignment”, Cho,H.J. & Huang,H. AIP Conference Proceedings, 963, 993 (2007)
- “The Public Health Costs of Traffic Congestion”, Harvard Center for Risk Analysis, Jonathan I. Levy, Jonathan J. Buonocore, & Katherine von Stackelberg (2010)
- “The future economic and environmental costs of gridlock in 2030”, Centre for Economics & Business Research (2014)
- “American Community Survey.” U.S. Census Bureau’s American Community Survey Office. 1 December 2016 <<http://ftp2.census.gov/>>.
- "OpenStreetMap contributors. (2015) Planet dump. Retrieved from <http://planet.openstreetmap.org>."

