6.336 Project Abstract

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Motivation

Drivers in the United States can waste up to 82 hours in traffic annually. In addition to incurring an annual cost of 124 billion dollars, road congestion also causes environmental damage. With increasing levels of population and environmental concerns, traffic congestion is becoming an urgent issue that city planners and policy makers have to consider, and tools that help analyze urban transportation are becoming increasingly relevant. In this project, we simulated and studied traffic behavior in Cambridge during peak hours, when people are commuting between work and home in the region shown in Figure 1.

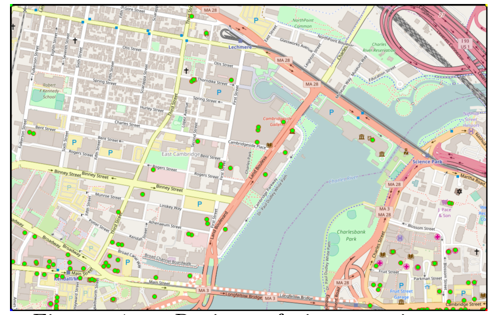


Figure 1: Region of interest in Cambridge.

Problem Formulation

Network

Input: Flow of cars from origins, flow of cars into destinations $\equiv \boldsymbol{f_{s,i}}$

Output: Congestion as a ratio of travel time to free flow travel time

Nodes: Geographical decision points	Components: Roads
Signals: Time from origin to node i, $\equiv \boldsymbol{T_i}$	Signals: Flow of cars $\frac{cars}{time}$, $\equiv \boldsymbol{f_a}$
Parameters: Free-flow-travel-time to node i, $\equiv \boldsymbol{T_{0,i}}$	Parameters: Capacity of road, $\equiv \boldsymbol{K_a}$,
	Proportionality constant $\equiv \boldsymbol{\beta_a}$

Equations

If $f_{i,j}$ is the flow from node i to node j, where A(i) is the set of all nodes connected to node i, the conservation of traffic flow gives us Equation 1, where where $f_{s,i}$ represents flow as a source or sink, and is 0 for all non-sources and sinks.

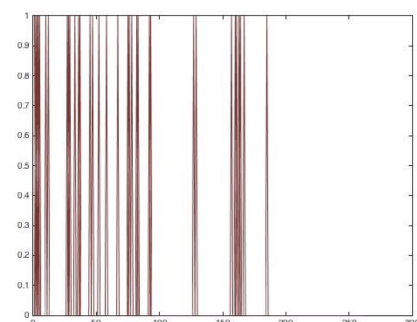
$$\sum_{j \in A(i)} f_{i,j} = f_{s,i} \textit{ for all i.} \qquad (1)$$

If we treat the cost of travel as the time required, the Bureau of Public Roads (BPR) [1] gives us the formulation represented by Equation 2, where $T_{0,i}$ is freeflow time from origin to point i.

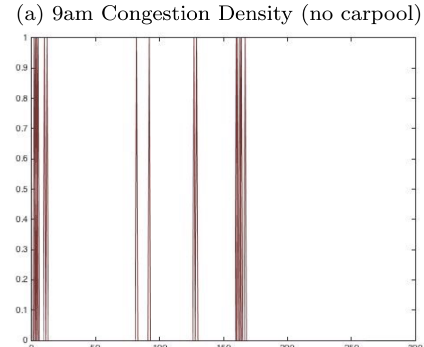
$$T_i - T_j = (T_{0,i} - T_{0,j})(1 + \beta_a (\frac{f_a}{K_a})^4) \textit{ for all a.} \qquad (2)$$

Results

Using data from OpenStreetMap [2], we built a network according to the specifications above, and ran steady state simulations using Node-Branch analysis together with regular newton method. Traffic flow volumes during hours when people are commuting between work and home in Cambridge (7am, 9am and 11am) were used as inputs and are derived from the US census [3]. We investigated congestion, measured in terms of $\frac{T_{ij}}{T_{0,ij}}$, and created a density plot (Figure 2a) to identify roads where the time taken for travel exceeds twice the free flow time, an indicator of heavy congestion. We then compared it to the congestion levels if we were to assume all drivers carpooled. Graphs comparing the density of congested roads at **9am** are given in Figure 2. From these graphs, we can see that mandated carpooling drastically lowers the congestion density. We also found that mandated carpooling would only provide marginal improvement to congestion at **7am** and **11am**. Also, we tested the road network with a constant input, equal to the traffic flow averaged over the peak hours, and tested whether or not the current infrastructure can support the expected traffic. We found that the current roads can support the average amount of traffic with much less congestion than is usually experienced; therefore, we conclude that congestion is an usage problem that could be solved with policies regulating the average load at a given time.



(a) 9am Congestion Density (no carpool)



(b) 9am Congestion Density (w/ carpool)

Figure 2: Comparison of carpool effects.

References

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

[2] Map data copyrighted OpenStreetMap contributors and available from `http://www.openstreetmap.org`

[3] "American Community Survey." U.S. Census Bureau's American Community Survey Office. 1 December 2016 `http://ftp2.census.gov/`