Information Percolation Systems on Traffic Management

Modelling and Simulation

M.EIC - Group 3 - 22/23

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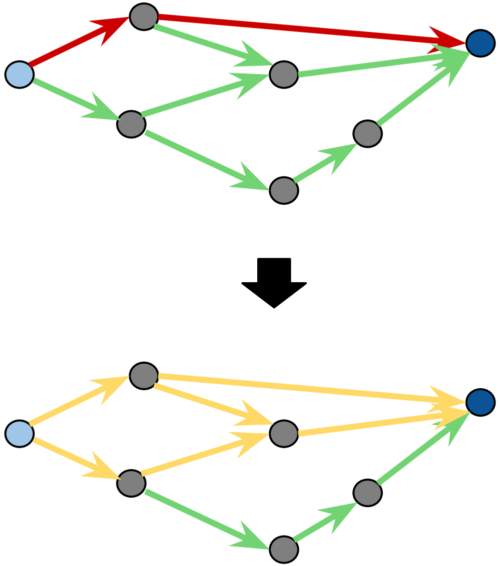
Problem Formalisation

Braess Paradox: the observation that adding one or more roads to a road network can slow down overall traffic flow.



How can information percolation (dissemination) be used to control traffic?

- CAVs (Connected Autonomous Vehicles)
- GPS and wireless smartphone communication

Motivation & Goals

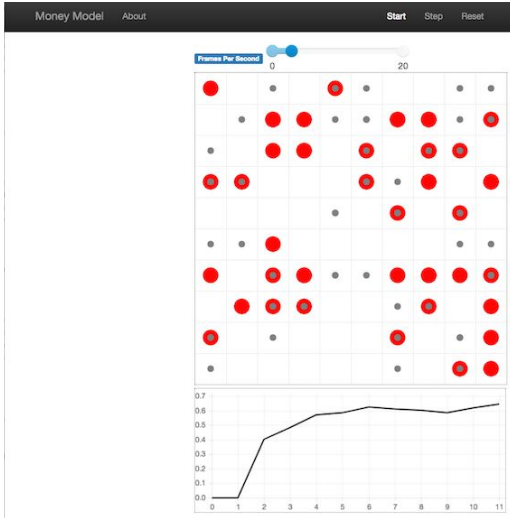
This project aims to develop a simulation environment capable of testing the impact of information percolation systems in the management of traffic networks and their congestion, specifically their ability to reduce overall travel time and congestion.

Concrete Objectives:

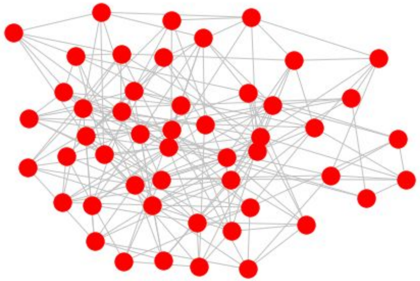
1. Model the behaviour of traffic evolution with BPR function
2. Model the typical behaviour for route choice through Descriptive Models
3. Model a possible new method as an Information Percolation System as a Speculative Model
4. Define and develop a simulation environment with multiple scenarios
5. Collect and analyze results regarding the impact of the operation policies in the different scenarios

Tools

Mesa: lightweight agent-based simulation library for python



NetworkX: lightweight graph construction library for python



Matplotlib - python library for creation and visualization of plots and graphs

BPR Function

Our project does not require data collection, as the data can be modelled itself. We can simulate the behaviour of a traffic network and model the travel time in accordance to the capacity and current volume of a given route using a **BPR (Bureau of Public Roads) function**.

The only Data Collection necessary is the one associated with minimally realistic Volume and Capacity values.

$$T_a = T_0 * (1 + \alpha * (V/C)^{\beta})$$

- T_a: time for travel
- T_0: travel time without traffic
- V: volume
- C: capacity

Tuned

$\alpha = 0.15$

$\beta = 4.0$

Gore, Arkatkar, Joshi & Antoniou (2023). Modified Bureau of Public Roads Link Function.

Models

Exogenous Variables:

Uncontrollable

- Traffic Network Configuration
- Vehicle Arrival Rate
- GPS Usage Ratio

Controllable

- Information Percolation Method - Vehicle Route Decision Strategy

Endogenous Variables:

- Average Travel Efficiency at 200
- Average Travel Time at 200
- Max Volume to Capacity Ratio at 200
- Steps until 200

Other details:

- Discrete simulation: one time step is roughly equivalent to 1 minute
- Agent-based: vehicles are agents

Models

Descriptive Model 1’s Operation Policy (Base): (no information percolation) has the vehicles go for the shortest route to the destination, as if the driver knew the shortest path or he was using a map or gps.

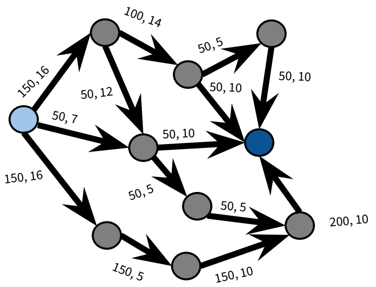
Descriptive Model 2’s Operation Policy (GPS): has the drivers choose the route with the lowest travel time according to the BPR function executed a few steps behind a percentage of the time, emulating a Google Maps system that estimates travel time with a certain delay.

Speculative Model’s Operation Policy (CAV): has the vehicles always go for the route with the lowest travel time according to the BPR in that moment, as if they were Connected Autonomous Vehicles that knew exactly the volume on each route, as they are in sync.

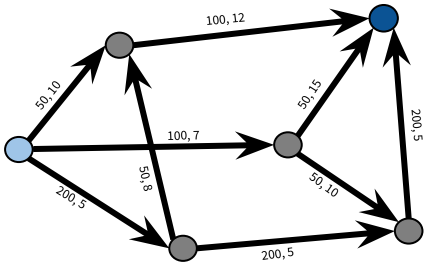
Scenarios

The scenarios are the result of the permutation of the following variables: <u>Information Percolation Scheme</u>, <u>Network Structure</u> and <u>Vehicle Arrival Rate</u>.

Traffic Networks



<u>Large</u>



<u>Medium</u>

Traffic Volume

1. 15
2. 20
3. 35

Operation Policy

1. Base
2. GPS
3. CAV

Decision Criteria and Performance

Performance Metrics:

- Average Travel Time at 200: average time taken by a vehicle to cover the (when the 200th vehicle finishes the path)
- Average Travel Efficiency at 200 (ATE200): ratio between the shortest time necessary for completion of a path without traffic with the average travel time (when the 200th vehicle finishes the path)
- Max Volume to Capacity Ratio at 200: illustrates the maximum congestion of any route in the network (when the 200th vehicle finishes the path)
- Steps until 200: number of simulation steps (mins) until 200 vehicles complete the path

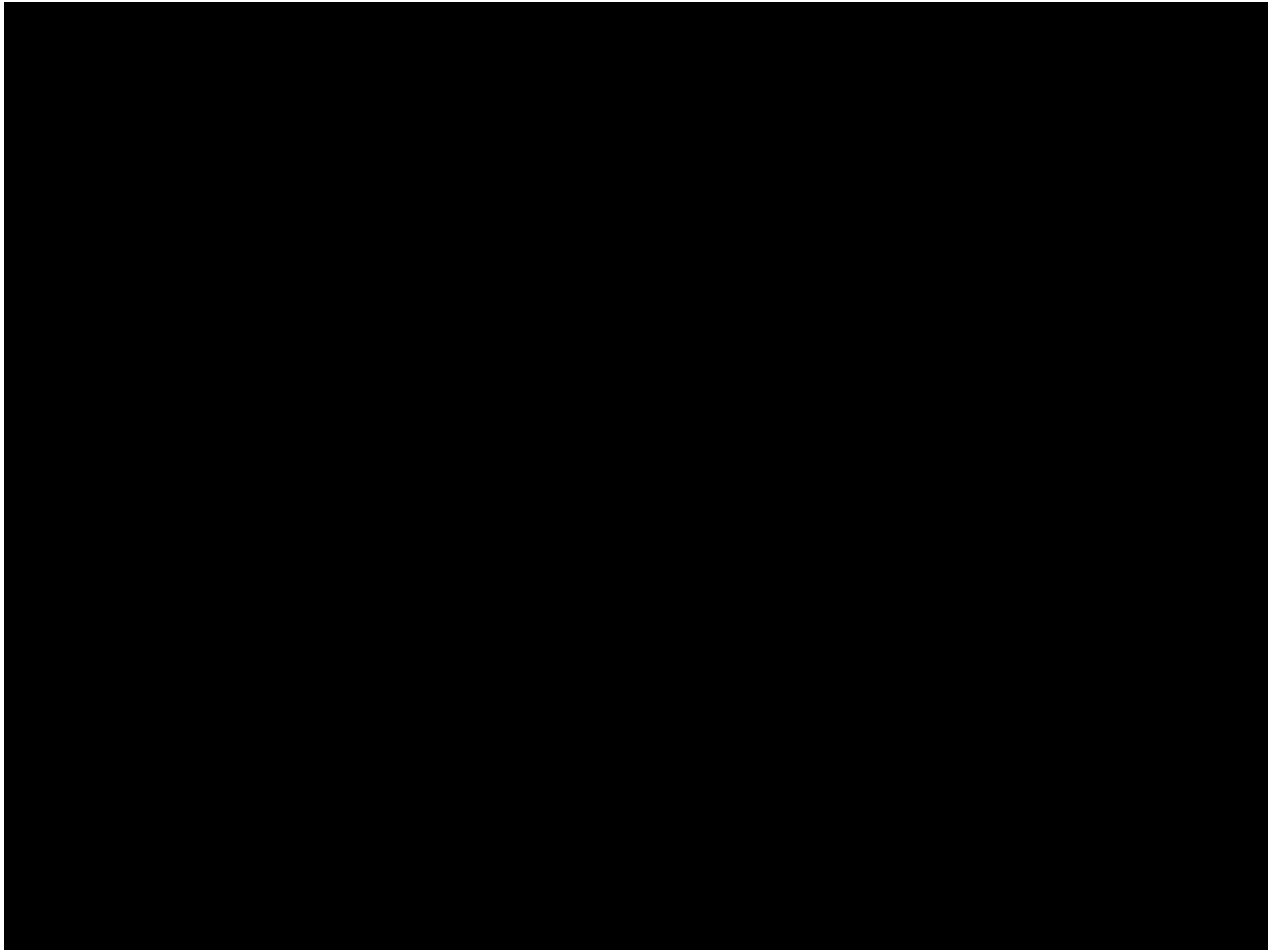
Decision Criteria and Performance

Performance Indicator: Average Travel Efficiency at 200 > 0.4

Decision Criteria:

1. If the CAV Model presents an improvement in ATE200 of more than 0.1 compared to the Descriptive Models, then the adoption of CAVs should be taken as a serious solution for traffic congestion problems
2. If a Model fulfills the performance indicator, its usage is deemed justified by this experiment

Demo

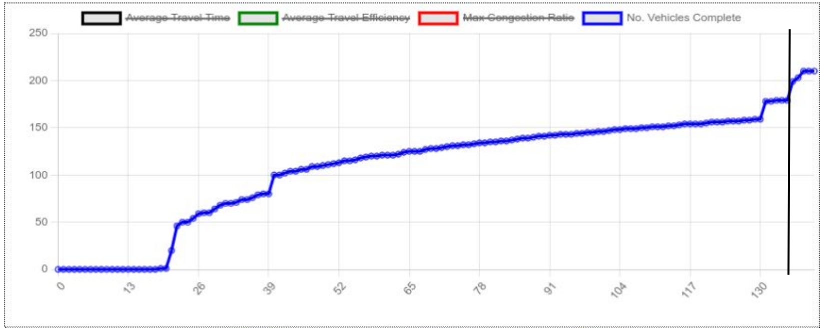


Results & Analysis

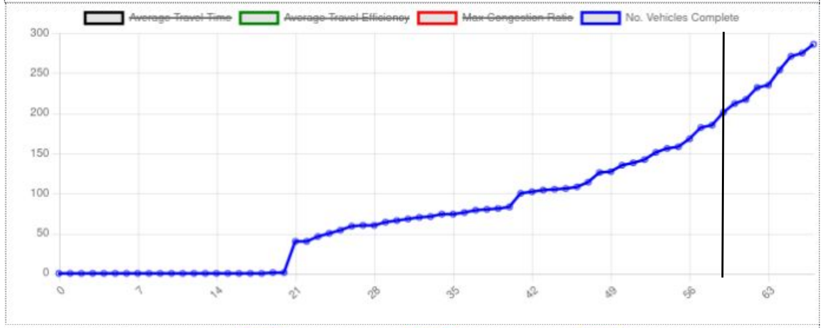
No. Vehicles Completed > Steps until 200

1. CAV
2. GPS
3. Base
   - Base Case performed significantly worse.
   - CAV was only marginally better than GPS

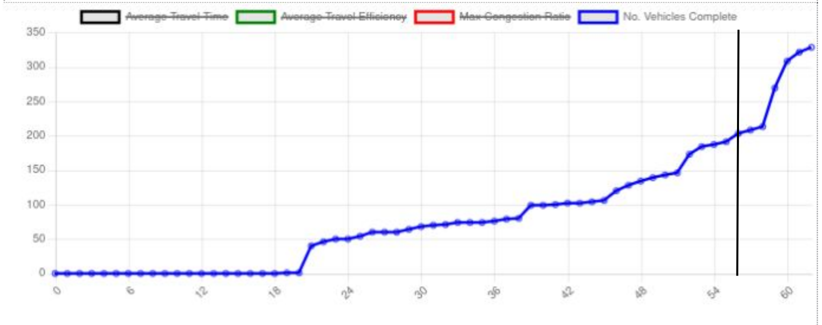
Base



GPS



CAV

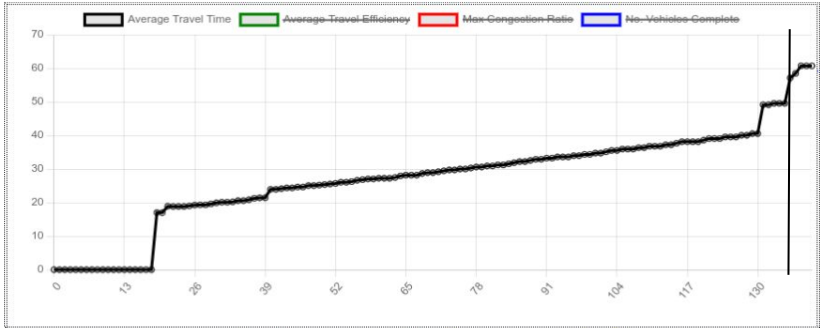


Results & Analysis

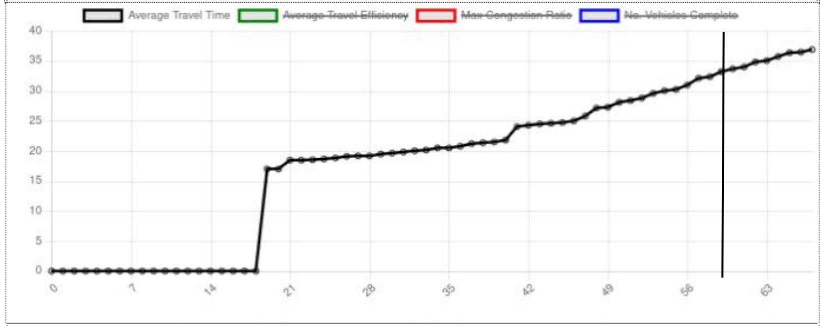
Average Travel Time

1. CAV
2. GPS
3. Base
   - Base Case performed significantly worse
   - CAV was only marginally better than GPS

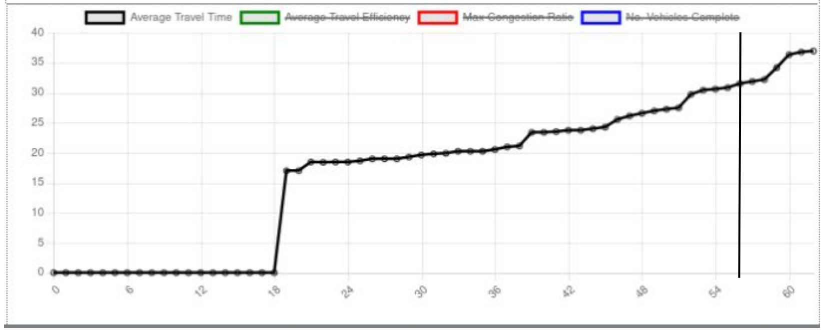
Base



GPS



CAV



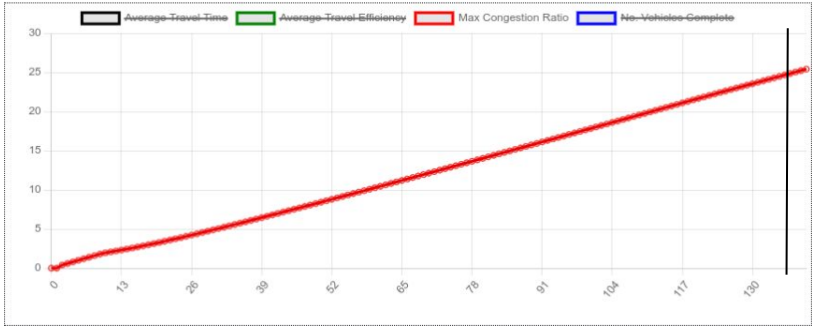
Results & Analysis

Max Congestion Ratio

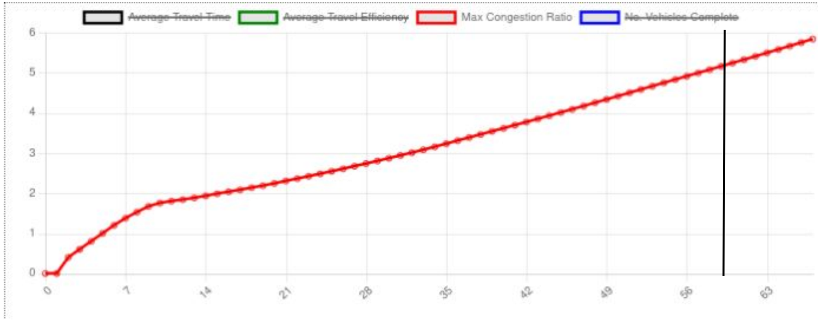
1. CAV
2. GPS
3. Base

- Base Case performed significantly worse
- CAV was only marginally better than GPS

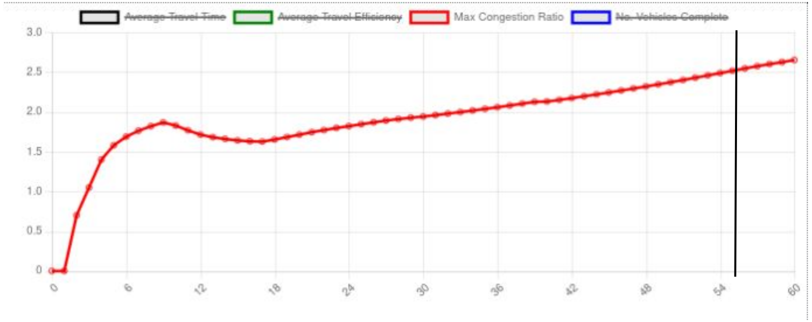
Base



GPS



CAV

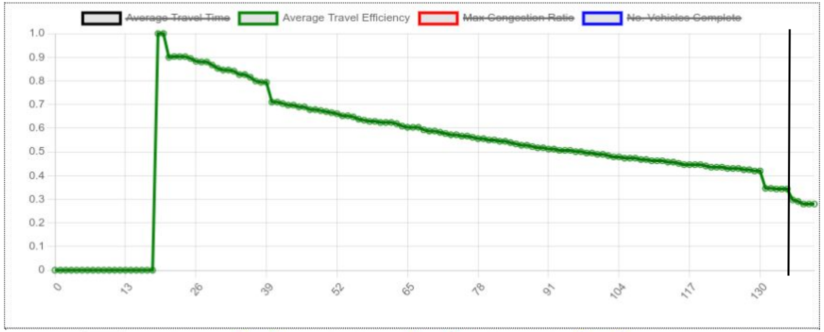


Results & Analysis

Average Travel Efficiency

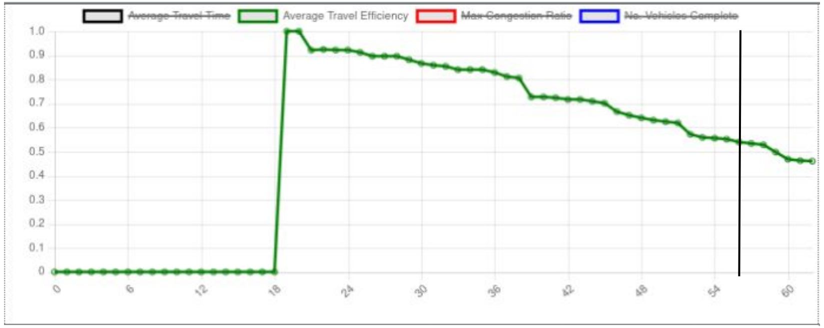
1. CAV
2. GPS
3. Base
   - Base Case performed significantly worse
   - CAV was only marginally better than GPS
   - Performance Criteria met by GPS and CAV

Base



GPS

CAV



Conclusions

In sum:

- both the Descriptive Model 2 (GPS) and the Speculative Model surpassed the performance criteria
- Only decision criteria 2. had grounds to be taken, meaning this experiment concludes Google Maps ‘like’ apps can work

Future Work:

- Increase validation - improve model fidelity by validating with real world data
    - Tuning BPR
    - More accurate data on Google Maps usage
    - More accurate data on capacity of routes and realistic traffic networks

Questions?