CE 269
Traffic Engineering

Lecture 1

Introduction

Welcome!

Introduction

- What's your name and where are you from?
- Where did you get your undergrad degree from?
- How did you get interested in transportation?
- Tell us something interesting about your driving experience.

Lecture Outline

1. Overview
2. Course Logistics
3. Measuring Traffic

Lecture Outline

Overview

Overview

Frequently Asked Questions (FAQs)

Why take this course?

- (CE students) For coursework-based M.Tech. students, this is a core course and you have no choice :)
- (Others) If you plan to do research on how traffic or pedestrians move, you're in the right class.

At the end of the course, you could be that guy from The Italian Job!

Overview

Frequently Asked Questions (FAQs)

What will I learn from this course?

- You will be introduced to various empirical and mathematical models that can be used for analysis and design of traffic.
- The course will also have a hands-on component, where you will model simple traffic scenarios using simulators and your own code.
- Most of the course will be prognostic in nature. That is, we will try to understand real-world phenomena and study how to design operational and infrastructure elements to avoid traffic problems.
- Study of diagnostic features, i.e., how we measure traffic will be rather limited.

Overview

Applications

Think of studying traffic as analogous to structural analysis and design. In the analysis part, you will understand the theory behind real-world traffic.

This helps with testing scenarios and operational aspects because we can simulate the effect of interventions.

The design part involves putting this knowledge into practice. It comprises of guidelines that have evolved (and continue to) from decades of research. They are mostly useful for long-range planning under 'average' conditions.

Being able to model and analyze different scenarios is thus paramount if you want to design good traffic systems. Most of this course will focus on the first part. You will get to study the second part through term projects.

Overview

Applications

What happens when a vehicle slows down on a highway? Why do phantom jams occur?

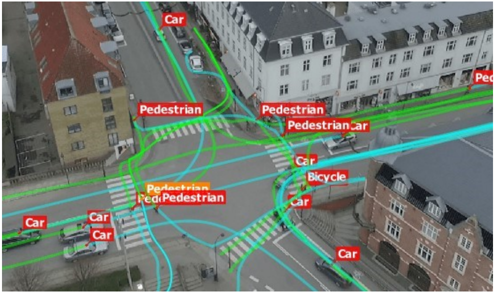
https://youtu.be/Suugn-p5C1M

When do people merge at unsignalized intersections or make lane changes?

Overview

Applications

Where are the conflict regions in a traffic network. How do they impact accidents.



Overview

Applications

How does traffic react to a certain control strategy such as signals?

https://youtu.be/4pbAI40dK0A

Do changes to geometric design improve traffic?

https://youtu.be/6OGvj7GZSIo

How to estimate the capacity or define the LoS of a roadway? Can we change road configurations dynamically?

- Analyzing behaviour of several individuals and modeling the heterogeneity in vehicle types and physics is tough.

- Traffic is closely connected with demand which is difficult to predict. Hence, reliable sensing infrastructure is required.
- It is also common to have several competing goals for improving traffic such as safety, congestion, cost, and emissions.

Lecture Outline

Course Logistics

Course Logistics

Prerequisites and Texts

Background in elementary calculus and computer programming in Python is a prerequisite for this course.

We will closely follow these books for the analysis parts of the course:

1. Ni, D. (2015). Traffic Flow Theory: Characteristics, experimental methods, and numerical techniques. Butterworth-Heinemann.
2. Treiber, M., & Kesting, A. (2013). Traffic Flow Dynamics: Data, Models and Simulation, Springer-Verlag Berlin Heidelberg.
3. Gartner, N. H., Messer, C. J., & Rathi, A. (2002). Traffic Flow Theory - A State-of-the-Art Report. TRB Special Report 165.
4. Knoop, V. L. (2018). Introduction to Traffic Flow Theory: An introduction with exercises. [PDF]
5. Boyles, S. Lownes, N. E., & Unnikrishnan, A. (2020). Transportation Network Analysis. [PDF]

These texts/manuals will be additionally used for some of the design portions.

1. Mannering, F. L., & Washburn, S. S. (2020). Principles of highway engineering and traffic analysis. John Wiley & Sons.
2. Wolshon, B., & Pande, A. (2016). Traffic engineering handbook. John Wiley & Sons.
3. Roess, R. P., Prassas, E. S., & McShane, W. R. (2004). Traffic engineering. Pearson/Prentice Hall.
4. Highway Capacity Manual, Sixth Edition: A Guide for Multimodal Mobility Analysis (2016)
5. Indian Highway Capacity Manual (Indo-HCM) (2017)

Note: Some of these references may describe right-hand traffic.

Course Logistics

Written Assignments

- The course will have four written assignments.
- You are encouraged to discuss the problems but **you must submit your own solutions**.
- Plagiarizing solutions from your peers or seniors is strictly prohibited.
- Anyone found guilty will of copying or sharing solutions will receive an F grade.
- After the submission deadlines, you may be randomly chosen to explain your solutions.

Course Logistics

Submission Guidelines

You are allowed a total of four late submission days which can be spread across the assignments. Assignments turned in after exhausting your quota receive zero points.

These assignments may also contain small programming tasks which should be submitted using Google Colab.

Ph.D. and M.Tech. Research Students

- The first two assignments must be prepared in LaTeX. You may use any TeX distribution or Overleaf.
- The remaining assignments can be prepared in any typesetting tool of your choice.

Others

- You must type and submit a PDF copy of your assignments, but you may use any typesetting tool.

Course Logistics

Term Project

The term project involves studying the design aspects of a traffic facility/technology in detail. You will be asked to select a topic from the following list.

- Roundabouts
- Flyovers
- Highway interchanges
- Toll plazas
- Parking lots
- Taxi stands
- Pedestrians
- Actuated signals
- Ramp metering
- Bicycle lanes
- Bus priority lanes
- Variable speed limits
- Modeling emissions
- Platooning
- AV Intersection management
- Dynamic lane reversal

You will have to make a presentation which will be graded by your classmates and submit a 10-12 page report.

Course Logistics

Exams and Grading

Examinations

- In-class exams: Mid-semester and End-semester
- End-semester exam is comprehensive

Grading

Component	*Percentage*
Written Assignments	30%
Mid-semester Exam	20%
Project + End-semester Exam	20% + 30%

All submissions must be made via Teams.

Course Logistics

Course Feedback

- The course will be split into modules and at the end of each module, you are required to provide anonymized feedback by answering if 'the contents of the module were clear and easy to understand?'
- Responses are to be provided on a Likert scale (Strongly disagree, Disagree, Neither, Agree, Strongly agree).
- These stats will help me calibrate the course content and also in picking the right questions for the assignments.

Course Logistics

Lecture Material

- Lecture slides for the subsequent weeks will be posted on the course website and MS Teams.
- Please read them in advance before coming to the class.
- Attendance is compulsory. Send me a message in advance in case you are unable to make it to the class.

Course Logistics

Office Hours

- Interactions during the class are strongly encouraged. Feel free to interrupt me any time during the lecture to get your doubts cleared.
- If you have additional course-related queries, we can discuss after the class or drop me a message on Teams to set up a call.
- A TA session will be conducted to help some of you get familiar with some fundamentals of programming and LaTeX.
- In addition, the TA for the course will be available between 13:00–14:00 every Monday.

Course Logistics

Modules

The course will be divided into the following modules:

- **Module I: Terminology and Microscopic Models**
  Variables used to describe traffic and measurement methods will be discussed. Microscopic traffic models for uninterrupted traffic will be introduced.
- **Module II: Macroscopic Models**
  Uninterrupted traffic will be revisited using macroscopic models.
- **Module III: Interrupted Traffic—Signalized and Unsignalized**
  Analysis of a single intersection (signalized and unsignalized), roundabouts, and a network of intersections will be discussed next.
- **Module IV: Special Topics**
  This portion will cover miscellaneous topics such as MFDs, DTA, and vehicle dynamics. It would also include a few guest lectures.

Measuring Traffic

Measuring Traffic

Sensors

Traffic measurement can be made using sensors that can be broadly classified into the following categories:

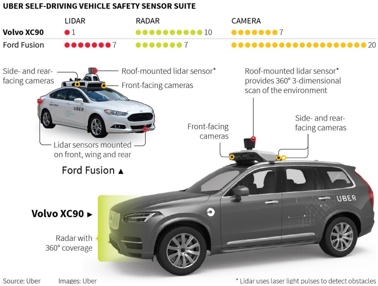
- Mobile sensors
- Point sensors
- Space sensors

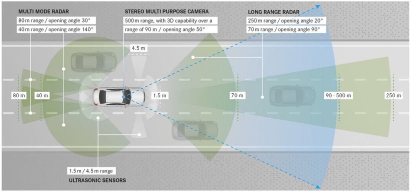
Measuring Traffic

Mobile sensors

Mobile sensors typically include GPS and cell phones (GPS, BLE, WiFi). Probe vehicles or service/utility vehicles can also be used for collecting traffic information.

They can however be more sophisticated for other applications such as pavement maintenance systems and autonomous vehicles.



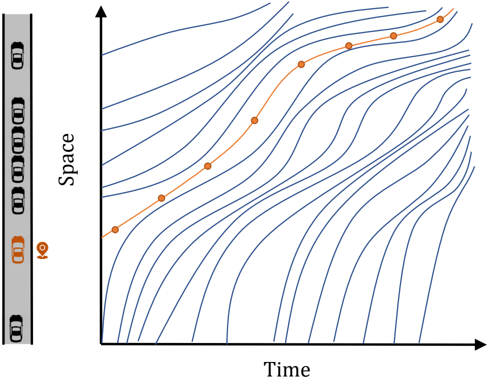


https://vimeo.com/192179726

What are the advantages and disadvantages of these types of sensors?

Measuring Traffic

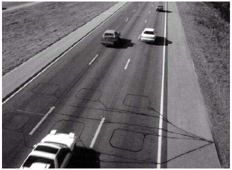
Mobile sensors

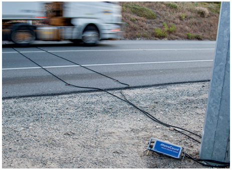


Measuring Traffic

Point sensors

Point sensors are fixed units at or inside the road and come in many forms such as loop detectors, cameras, pneumatic tubes, parking sensors, IR sensors, RFID, and BLE.



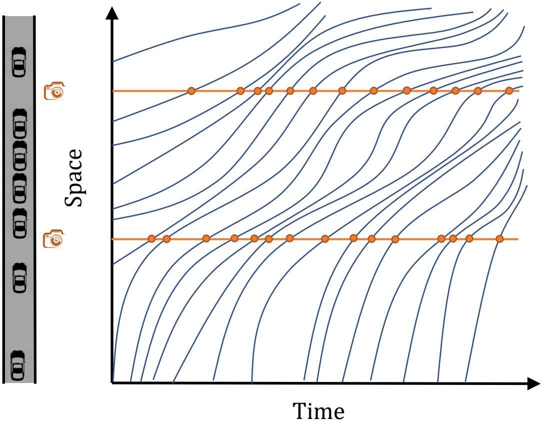



What are the advantages and disadvantages of these sensors?

Measuring Traffic

Point sensors

Multiple point sensors can be used to capture spatial variation in traffic.



Measuring Traffic

Space sensors

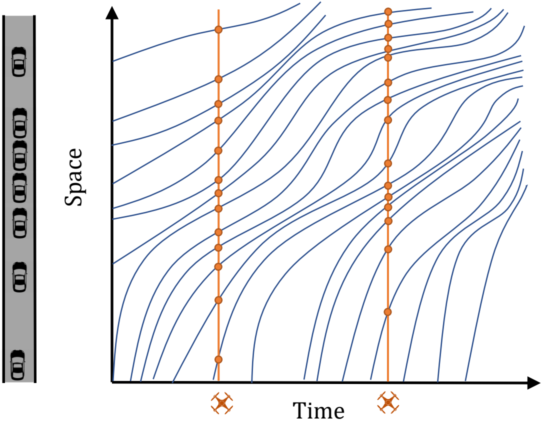
Space sensors can capture traffic data across both space and time. Examples include drones, depth cameras, and aerial imagery (satellites).

https://youtu.be/XwzbFzqhF1Y

What are the advantages and disadvantages of these sensors?

Measuring Traffic

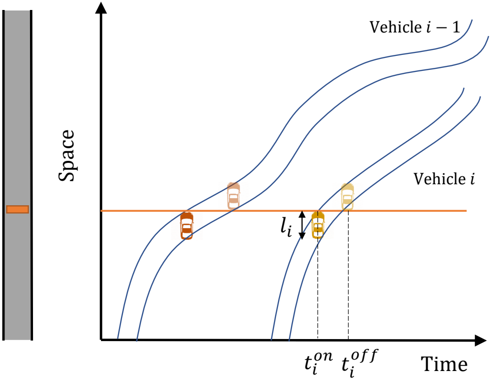
Space sensors



Measuring Traffic

Variables from Point Sensors

Let us first look at the variables that can be calculated using the most commonly used point sensors.



We number the vehicles in the increasing order of appearance at the point sensor.

Measuring Traffic

Variables from Point Sensors

Flow or Flux: Is defined as the number of vehicles passing across a point in a given amount of time T.

$$q = \frac{\Delta N}{T}$$

Occupancy: It measures the amount of time the detector is active/on.

$$o = \frac{\sum_i (t_i^{off} - t_i^{on})}{T}$$

Measuring Traffic

Variables from Point Sensors

Headway: It is the time taken between the arrivals of the front end of successive vehicles.

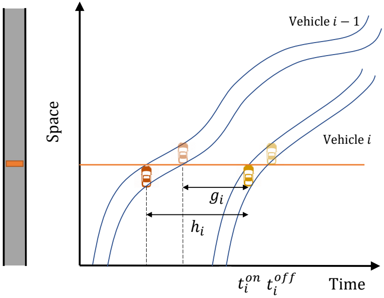
$$h_i = t_i^{on} - t_{i-1}^{on}$$

Note that a vehicle's headway is defined with respect to the vehicle in front.

Gap: It is the time between the arrival of the arrival of the rear end of the lead vehicle and the front end of the following vehicle.

$$g_i = t_i^{on} - t_{i-1}^{off}$$

Gap may be viewed as the time to collision if the lead vehicle came to an abrupt stop.



Flow and average of the headway are related to each other.

$$q = \frac{\Delta N}{T} = \frac{\Delta N}{\sum_i h_i} = \frac{1}{h}$$

Speed: Speed of individual are easy to measure using mobile sensors (Why?) Using point sensors, we can compute average of speeds across multiple vehicles. This is called **time-mean speed**.

$$v_t = \frac{1}{\Delta N} \sum_i v_i$$

A vehicle's speed can be measured if it's length l_i is known.

$$v_i = \frac{l_i}{t_i^{off} - t_i^{on}}$$

If a loop detector of width d is used, the numerator can be replaced by $d + l_i$.

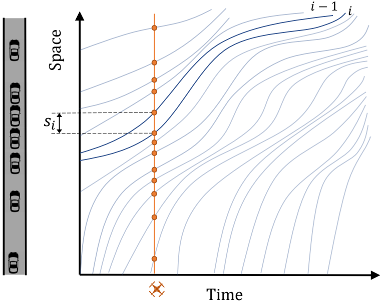
Spatial description of traffic from typically takes the form

Density or Concentration: It is the number of vehicles in a unit length of the road.

$$k = \frac{\Delta N}{L}$$

Spacing: It is the distance between the current vehicle and its lead vehicle.

$$s_i = x_{i-1} - x_i$$



Temporal information from such sensors can be obtained by taking multiple snapshots.

Just as flow and average headway, density and average spacing are also inverses.

$$k = \frac{\Delta N}{L} = \frac{\Delta N}{\sum_i s_i} = \frac{1}{s}$$

Speeds of individual vehicles can also be aggregated across space to derive **space-mean speed**.

$$v_s = \frac{\sum_i v_i}{L}$$

Measuring Traffic

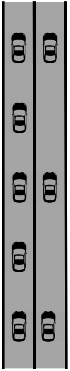
Speeds

Time- and Space-mean average speeds are usually different, especially when traffic conditions are not homogeneous.

For example, consider a two-lane highway where each car in the right lane has a speed 60 kmph and that on the left lane has a speed 30 kmph.

Suppose that the vehicles are uniformly spaced and that the flow of vehicles on both lanes is 1200 vehicles per hour.

What are the time- and space-mean average speeds?



Your Moment of Zen

https://youtu.be/7UF-S2czdCk