CE 205A
Transportation Logistics

Lecture 0

Introduction

Welcome!

- What's your name and where are you from?
- (For PG students) Where did you get your undergrad degree from?
- How did you get interested in transportation?
- Tell us something interesting about yourself.

Lecture Outline

Overview

Overview

Frequently Asked Questions (FAQs)

Why take this course and what will I learn from this course?

- Because your advisor asked you to take it :)
- Many problems in logistics are formulated as optimization models. You will get to convert practical requirements into mathematical constraints.
- A major focus of this course will be techniques for solving these problems. You will not only get exposed to the classic problems in this area but will also learn and code popular algorithms for solving them.

Can I not just use a library or a solver?

- Yes, libraries such as OR-Tools, CPLEX, LINDO, COIN-OR, and SCIP will help to some extent.
- However, even before we attempt use these tools, we must be able to formulate a problem in an efficient manner.
- Most problems we will encounter are NP-Hard problems and hence elementary methods will not scale well. Thus, off-the-shelf tools will work well only on small instances.
- We will study some of the methods that run behind these solvers which will help you design your own approaches for instances with a special structure.

Overview

Scope

The area of logistics is very broad. In this course we will not focus on the demand aspects, but instead only deal with supply optimization.

Specifically, we will look at a subset of classic problems in last-mile logistics. Real world problems are often more constrained depending on operations in the field but modeling these extensions will not be a challenge after you finish this course.

We will also only deal with offline problems where the parameters (customer locations, demand, etc.) are deterministic and do not change during the course of operations. Imagine operations of Bigbasket or Amazon/Flipkart for reference.

Overview

Scope

Problems in transportation logistics can be broadly classified in the following manner:

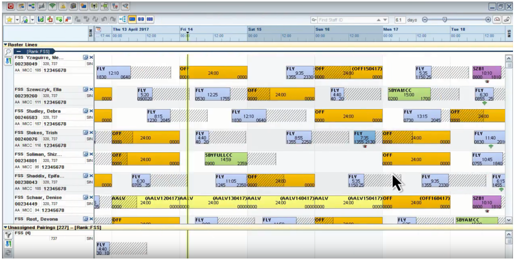
1. Routing
2. Matching/Assignment/Scheduling
3. Location
4. Flow

A complete logistical and supply chain system typically involves more than one or all of the above problems.

Routing Problems:
Most of the course will focus on these type of problems. These form the crux of most logistical operations. We will explore classic problems such as traveling salesperson problem and vehicle routing problem and their variants.

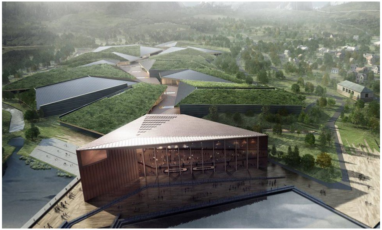
Source: Popular Mechanics

Matching/Assignment Problems:
Matching/Assignment/Pairing problems appear in pairing or grouping entities to optimize a certain common objective. Examples include crew scheduling, assigning buses to trips, and drivers to customers or pickup locations (for on-demand delivery systems).



Source: Altexsoft

Location Problems:
Location problems are strategic and involve deciding the placement of warehouses and depots, charging spots, data centers, etc. Network design problems can also be viewed as location problems where the goal is to design the routes on which vehicles would operate.



Source: BBC, Amazon

Overview

Scope

Flow Problems:
Flow problems are usually continuous and can be solved more efficiently compared to the other three categories of problems. For example, maximum flow and minimum cost problems (single and multi-commodity) problems can be solved using polynomial-time algorithms.

Source: TomTom

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Prerequisites and Texts

A course on optimization is a prerequisite for this course. You must be comfortable in linear/convex programming. We will also use CPLEX and NetworkX throughout the course and hence proficiency in Python is assumed.

The following books can be used as references for this course:

1. Wolsey, L. A. (2020). Integer programming. John Wiley & Sons.
2. Toth, P., & Vigo, D. (Eds.). (2002). The vehicle routing problem. Society for Industrial and Applied Mathematics (SIAM).
3. Gutin, G., & Punnen, A. P. (Eds.). (2006). The traveling salesman problem and its variations (Vol. 12). Springer Science & Business Media.
4. Applegate, D. L. (2006). The traveling salesman problem: a computational study. Princeton university press.

Additional review papers and book chapters will be shared if required.

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Assignments

Students will be graded on a 100-point scale. The weights for different components of the course are as follows: programming assignments (60%) and final project (40%).

- The course will have 5 programming assignments.
- You are encouraged to discuss the problems but **you must write your own code**. GPT/Co-Pilot are allowed.
- Plagiarizing solutions from your peers/seniors or online sources is strictly prohibited.
- Anyone found guilty will of copying or sharing solutions will receive an F grade.

All codes must comply with PEP 8 or Google Python style guides.

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Assignments

We will use **GitHub Classroom** for assignment submissions. The evaluation will be done in a competition mode and will involve two rounds.

- In Round 1, all submissions will be evaluated on the same machine for accuracy and run times. The results will be posted for everyone to see.
- You will receive an additional week to improve your codes and submit them for re-evaluation in Round 2. Only those who submit their solutions in Round 1 are eligible to compete in Round 2.

Each assignment is worth 12 points. More details for the scoring will depend on the assignment and more details will be provided later.

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Final Project

For the final project, you can chose from one of the following two tracks:

Implementation Track: You are required to replicate the results from a paper on logistics that has been published in the last two decades.

Research Track: You can pick a new problem and formulate an optimization model, propose a solution that performs better than existing literature on benchmark datasets. The final submission must be of publishable (or nearly publishable) quality.

Evaluation split: Performance of proposed solution methods (20 points), presentation (10 points), and code quality (10 points).

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Lab Component

We will meet for an additional hour once every 2 weeks for the lab sessions.

We will discuss programming-related aspects of the course which will be of use for your assignments and projects.

Attendance for the lab component is mandatory. The programming assignments and feedback on your submissions will be discussed during the lab hours. Please bring your laptop for these sessions.

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Lecture Material and Office Hours

Lecture slides for the subsequent weeks will be posted on the course website and MS Teams.

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.

Attendance is compulsory. Send me a message in advance in case you are unable to make it to the class.

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Modules

The course will be divided into the following modules:

- **Module I: Background**
  In this part, we will cover some background on linear and integer programs including branch and bound. You are expected to be aware of these concepts. This module is mostly a refresher on these topics.
- **Module II: Classic Logistic Problems**
  We will discuss formulations for classic logistic problems such as TSP, VRP, matching and location problems. Computation complexity will also be briefly covered.
- **Module III: TSP and Cutting Planes**
  Cutting planes are at the core of any integer programming solution method. In this module we explore cutting planes for general polyhedral constrains and then study valid inequalities specific to the TSP.

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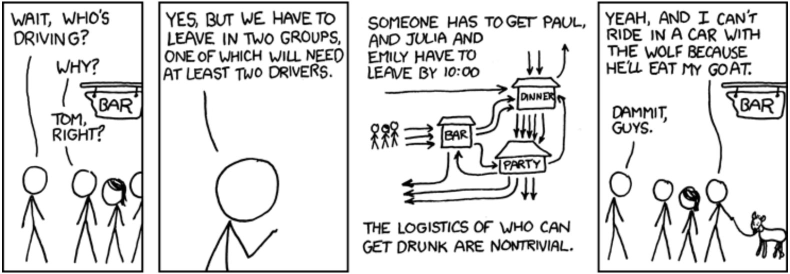
Modules

- **Module IV: VRP and Column Generation**
  Column generation and related methods (Branch and Price) is another popular method to solve large scale routing problems. These will be motivated using VRPs.
- **Module V: Miscellaneous Topics**
  In the final module, we will cover heuristics to solve TSPs and VRPs. Vehicle and crew scheduling problems will also be discussed. A couple of lectures will introduce you to collaborative logistics.

Your Moment of Zen



Source: xkcd