Optimization Based Approaches for Logistics

Workshop on Emerging AI Technology for Decision Making in Maritime Domain

INS Valsura

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Overview

- Three studies on ground-based logistics
- In cooperation with industrial collaborators

- Special thanks to:
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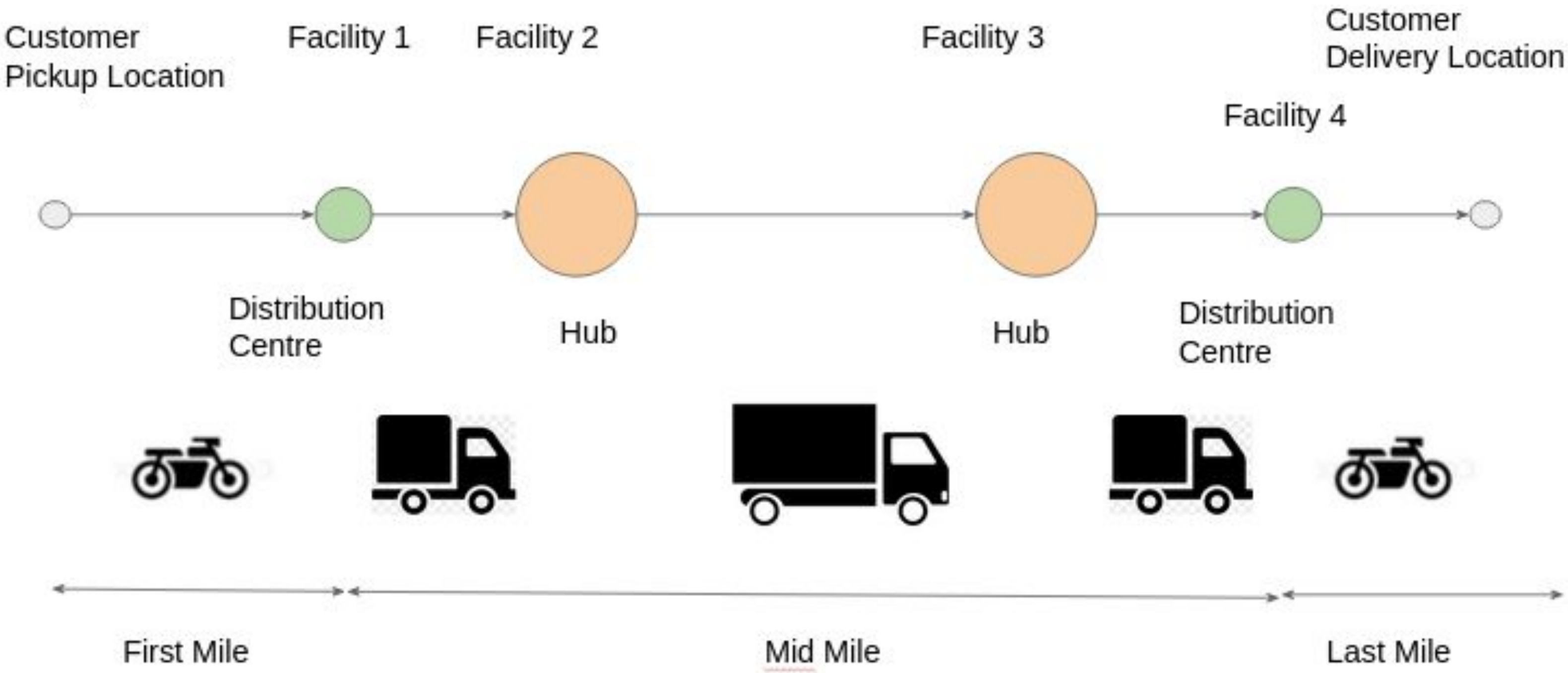
I - Last Mile Operations in Delivery

- Package pickup and delivery nation-wide
- Door to door operations



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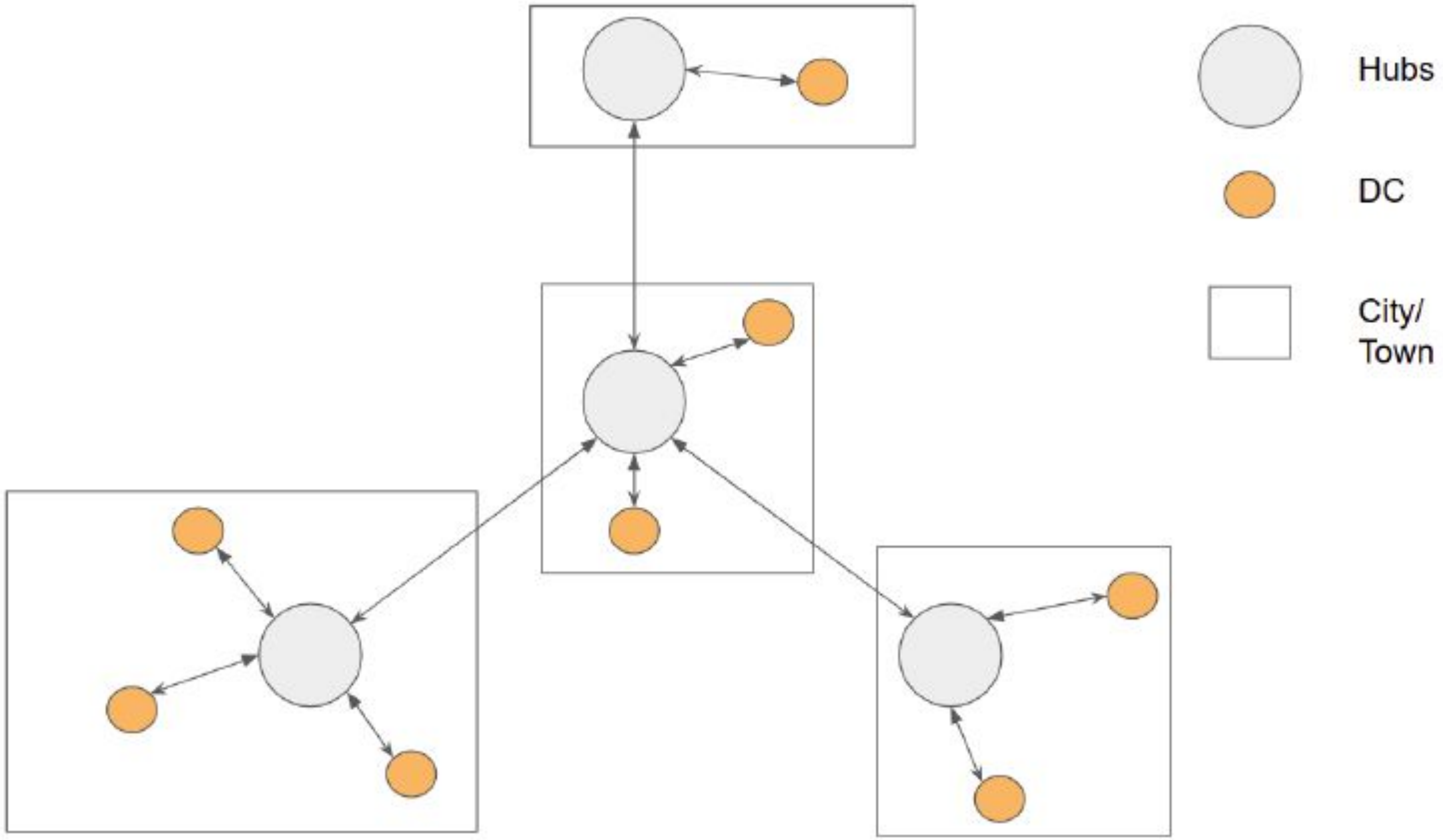
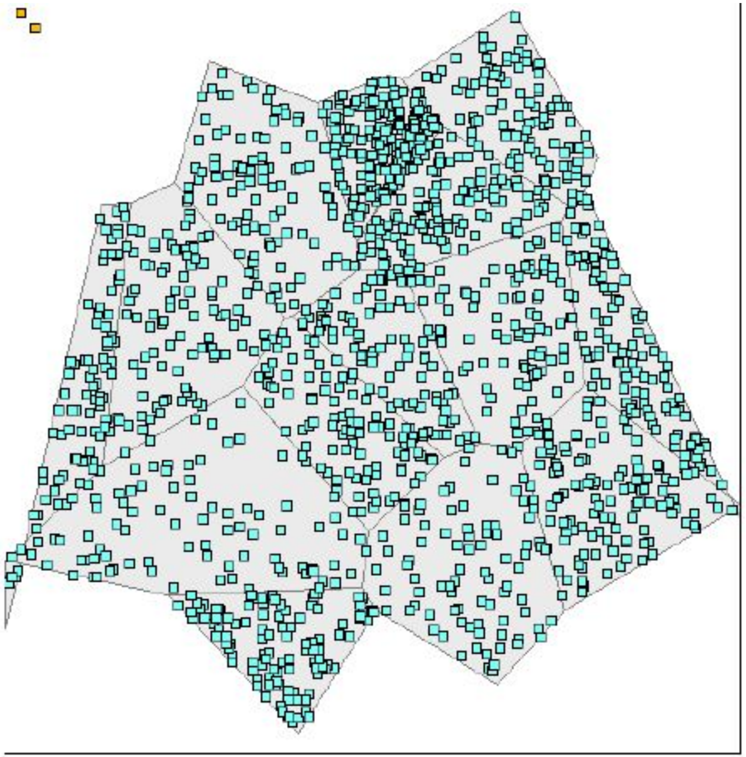
Network View



Last Mile Operations

- Packages arrive at a distribution center in bulk
- Need to be delivered to end points distributed over a geographical region
- Part of a city or the whole town
- Many small consignments
- Large team of delivery agents and managers
- Similar to First-mile (in reverse)



Last Mile Operations

Questions:

- Allocation: Which agent delivers which packets
- Sequencing: In which order an agent should visit the end points

Objectives:

- Service quality – all orders be delivered in promised-time
- Cost – minimize the cost of traveling, hiring extra resources

Desired:

- Good solutions to help manager at the distribution center
- Flexible, intuitive, every-day

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Constraints

- Vehicle capacity and type
- Number of vehicles and riders
- Time-windows of operations
- Time-windows of deliveries
- Agents’ familiarity with the area

Scale (per DC per day):

- 35 vehicles and agents
- 1000+ packages

Proposed Solution

- A mathematical model is designed
- Key decisions are the variables or unknowns in the model
- The model is solved using a mathematical optimization solver
- Solution is interpreted into decisions to be taken

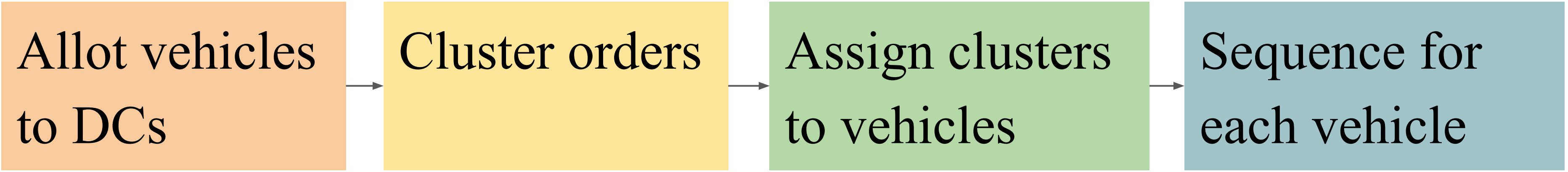
- Model is developed once
- Solved daily with the inputs for that day’s operations
- Can help in doing what-if analysis (design)

Mathematical Model

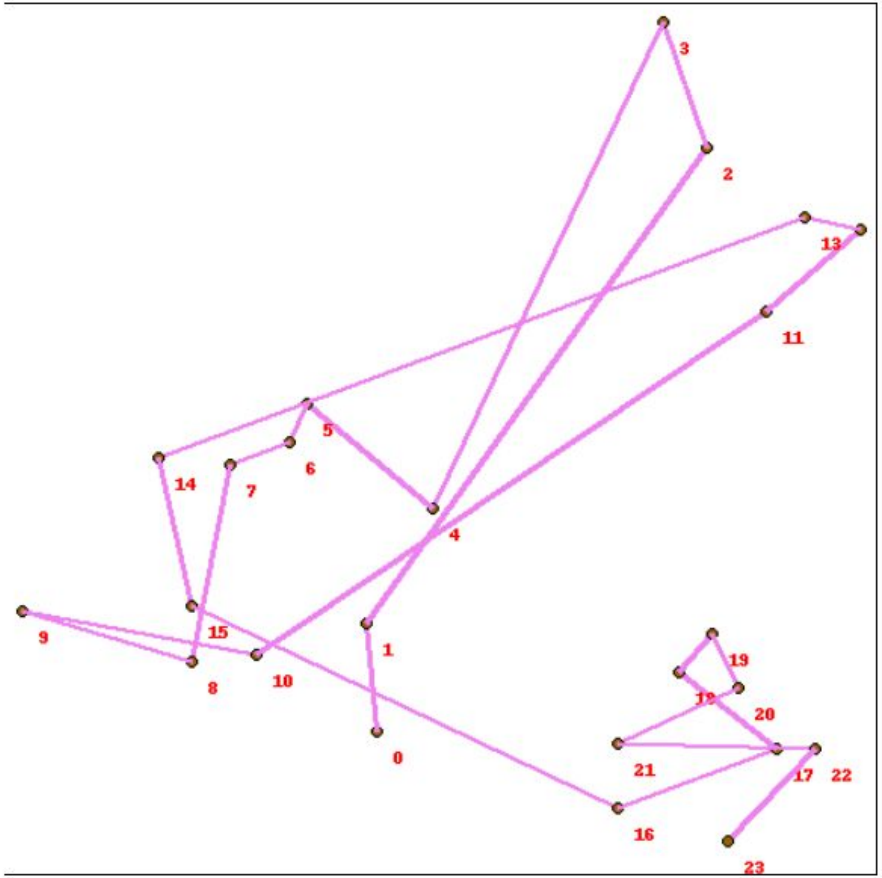
- Similar to Vehicle Routing Problem commonly seen in Operations Research
- Several side constraints:
  - Time windows
  - Agents' familiarity with geographical areas
  - Multiple DCs (in big cities)
- Too hard to solve in reasonable time
- Even heuristics (hit-and-trial) or local search do not give good quality results

Solution Approach

- Break the planning problem into smaller decisions
- Solve the each subproblem optimally
- Usually gives near-optimal solution for the full model

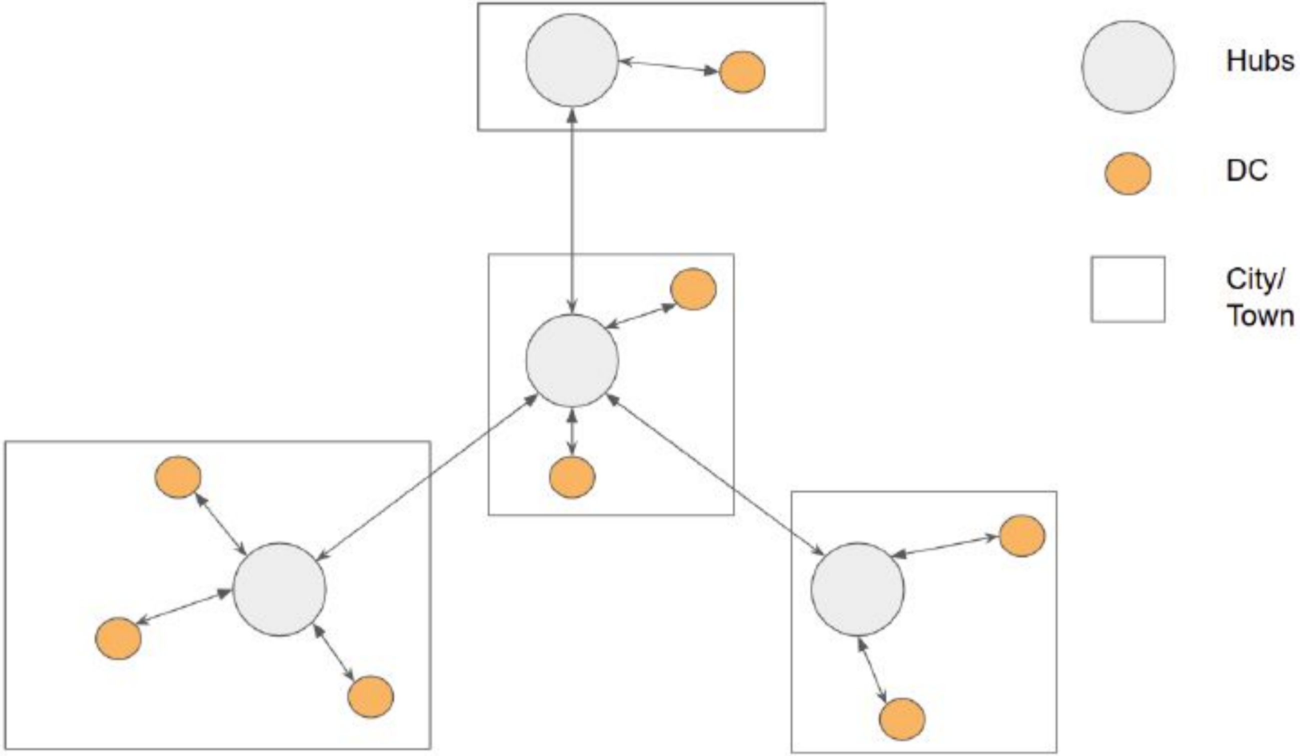


A Sample Path of a Vehicle



II – Mid Mile Operations

- Similar network as earlier
- Focus on consolidated movements between big cities



Mid-Mile Operations

- Large trucks carry consolidated loads from one hub to the other
- Savings in cost

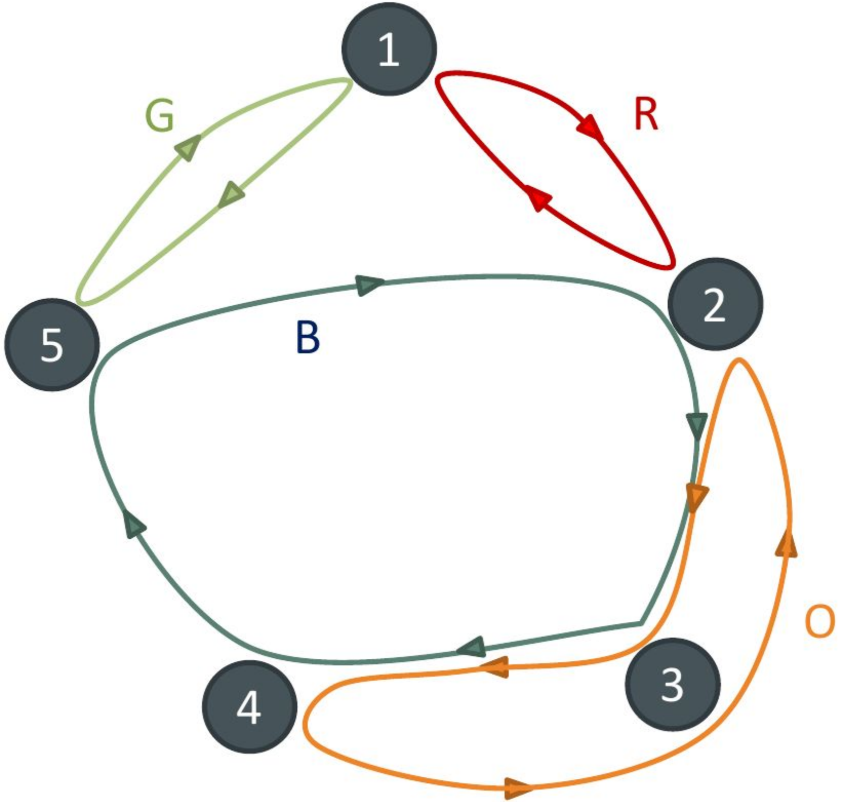
Questions

- How many trucks do we need?
- Route of each truck.
- Daily/Weekly schedule of each truck.

- Not as dynamic as last-mile
- Prefer periodic timetabling
- Contracts formalized based on demand estimates

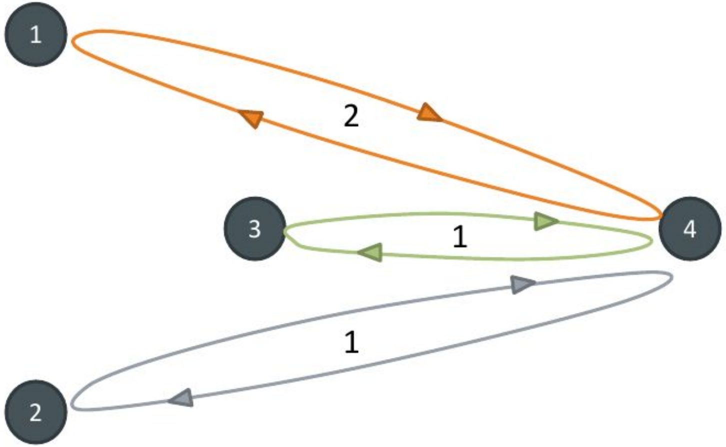
Routing Trucks

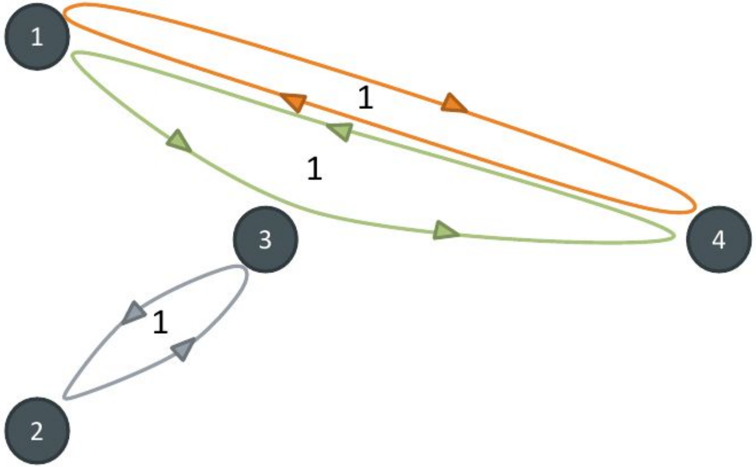
- How to ensure connectivity?
- For the shown network
- 10 trucks are required if we want to connect all pairs
- A single truck moving 1 → 2 → 3 → 4 → 5 → 1 will suffice
- … but will be slow
- What is the optimal tradeoff?



Truck Utilization

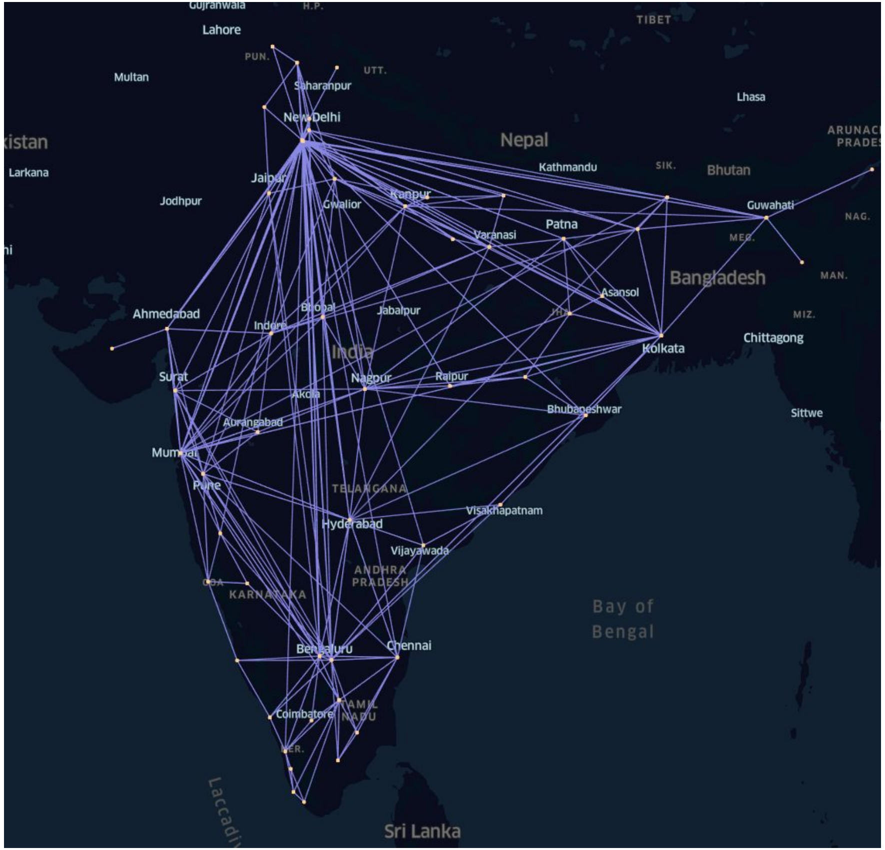
- If volume of $1 \rightarrow 2$ is same as $2 \rightarrow 1$, then a truck can shuttle back-and-forth
- Usually the demands are unbalanced, implying empty returns
- Can take detours to avoid empty travels

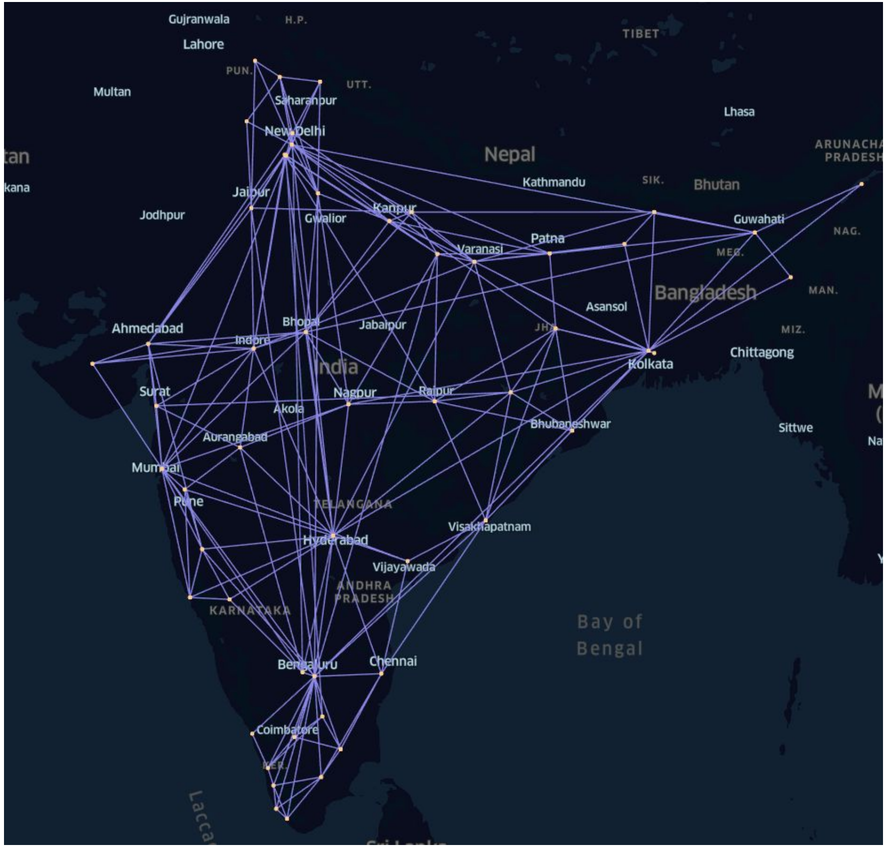




Solution Approach

- Consider only 2, 3 and 4 node circular routes
- For a 60-node network (pan India):
  - 2-node routes: 1,770
  - 3-node routes: 34,220 x 2
  - 4-node routes: 4,87,635 x 2
- Mathematical optimization model to maximize truck utilization over these routes only
- Constraints to ensure connectivity between all pairs
- Huge optimization model → Several hours to solve on a big server





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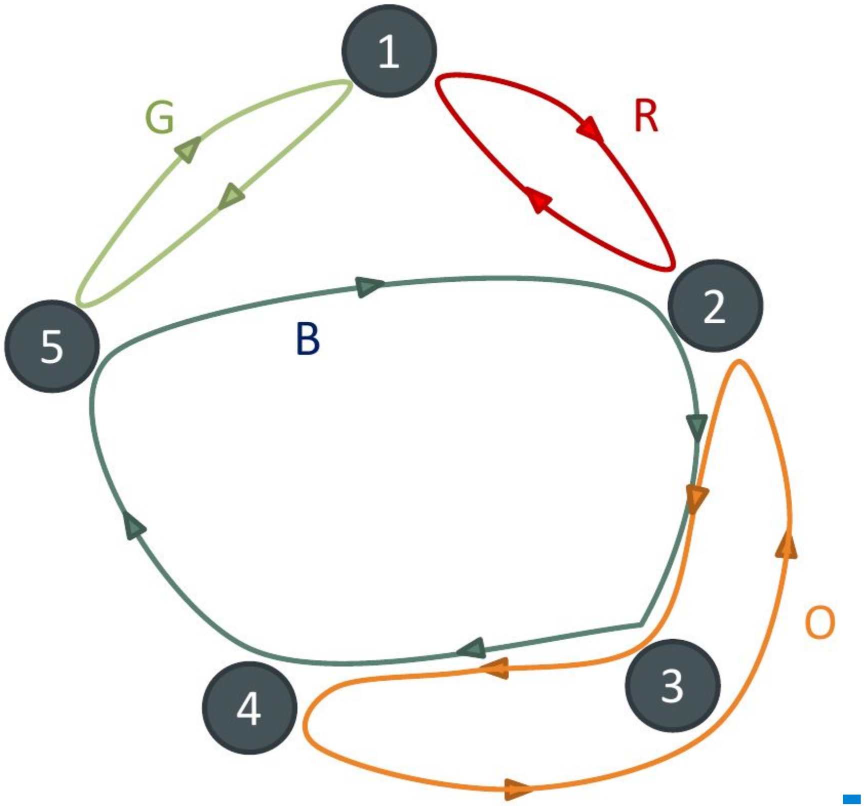
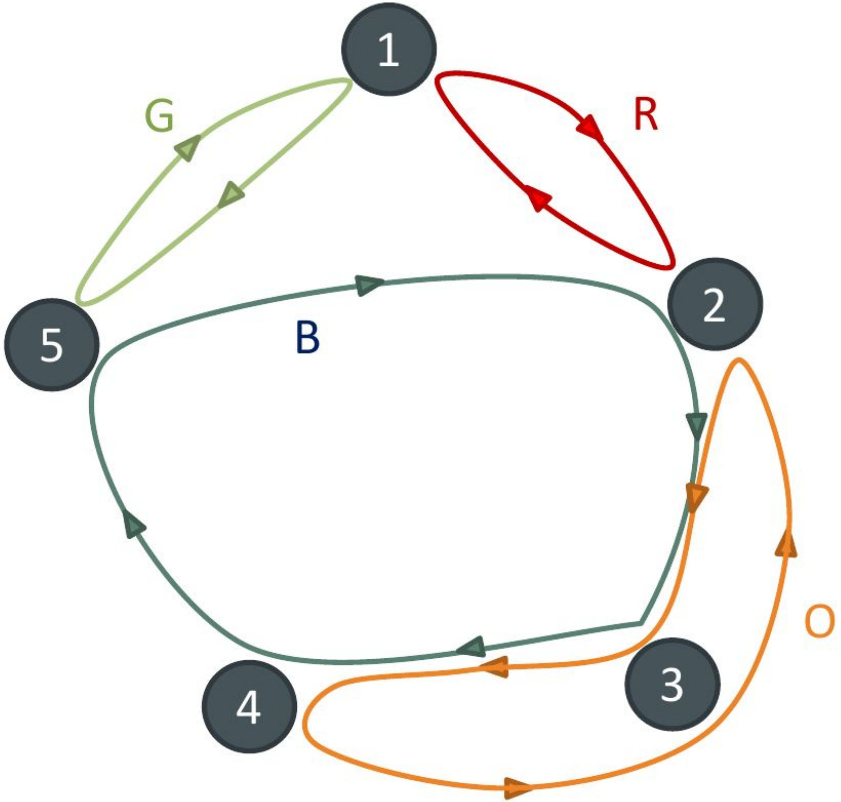
Routing and Scheduling

- Multiple routes possible from $4 \rightarrow 1$
- Which one to choose?
- What should be daily departure times for trucks on each route?



2nd Stage Problem

- Choosing routes from previous stage, find optimal times of despatch
- … and optimal choice of route for going from 4 → 1
- If some target times are breached, add more trucks and routes.

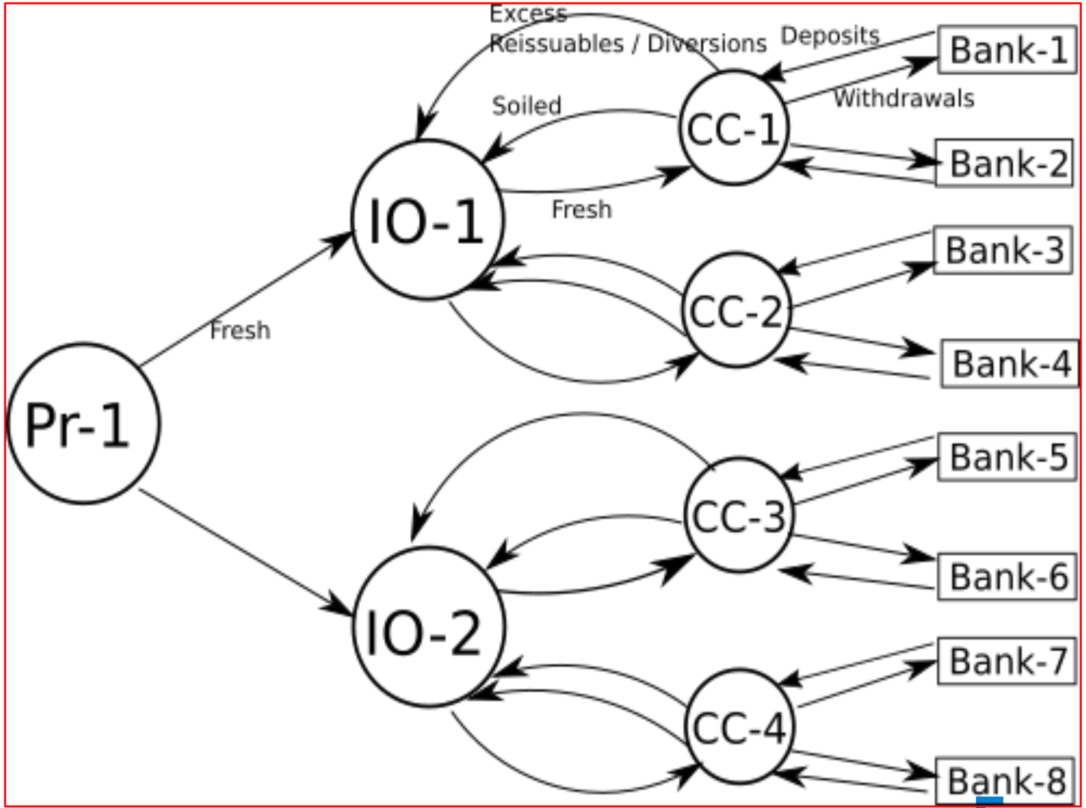


Mid-Mile Operations

- More of a design problem
- Design once, operate daily
- Many other side constraints and additional complexities ignored
- The solution needs to be verified and validated
- Simulation is a good tool to verify for fluctuating demands

III - Currency Flows

- Movement of currency
- Press →Issue Office →Currency Chest →Bank
- Looked at several questions
- Where should currency chests be located



Constraints

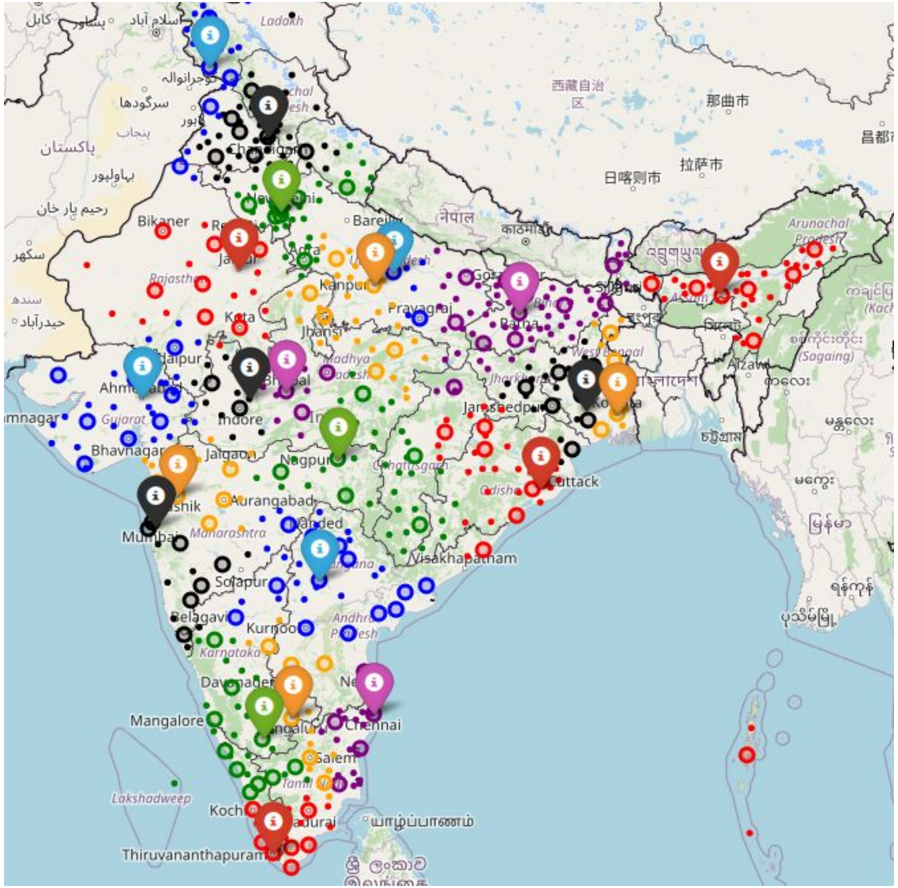
- Goods are moving both forward and backward (excess is deposited)
- All districts must be served
- Minimize cost of movements
- Fixed number of facilities are allowed

Optimization Model

- An optimization problem to choose which facilities should function
- Granularity is the district: facility present or not in a district is decision variable
- Withdrawals and deposits are given
- Ensure flow conservation at all facilities
- Minimize transportation cost between facilities and between facilities and districts

Solution

- Modelled as an integer optimization problem
- 750 decision variables (facility in a district on or off)
- 750x750 variables: which facility serves a district
- Solved using a solver on a server
- Gives an idealized solution, that can be modified



Summary

- Many problems in logistics can be solved mathematically
- Human intelligence required in modeling
- Technology available … and improving fast
- Still huge opportunities in India to improve efficiencies using Mathematical Optimization
- IEOR at IIT Bombay will be happy to collaborate
- Contact us:

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