Project 7: Data-Driven Optimization with Digital Twins for City Logistics

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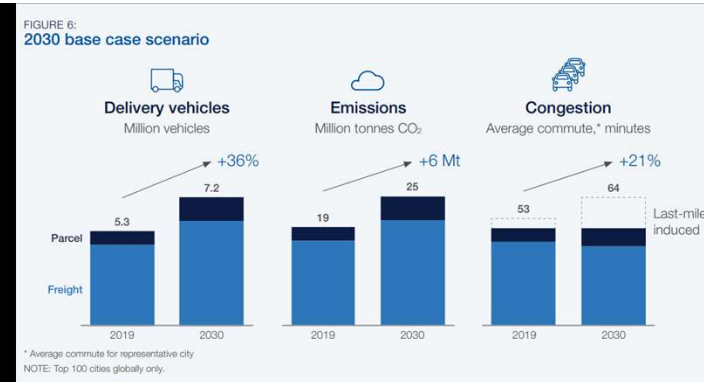
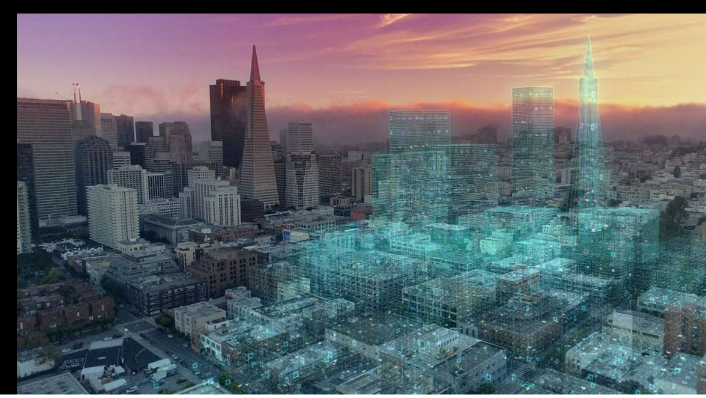
AI Planner of the Future

Background

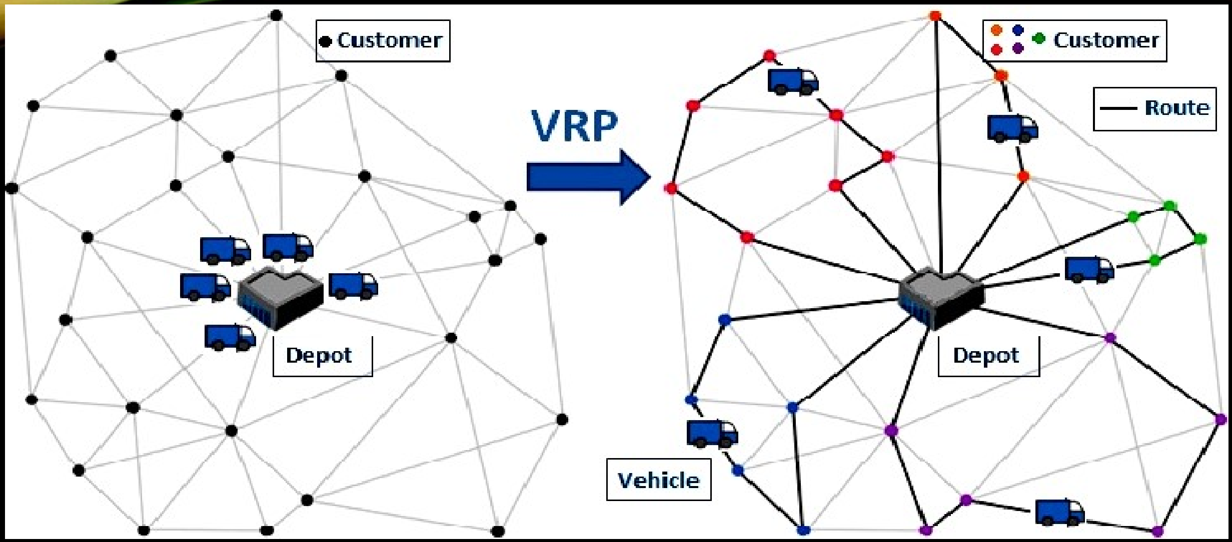
- Purpose of project is to aid our industrial partners with better planning of their urban supply chains.
  - Using computing power of smart technologies and AI.
  - To make cities more sustainable.

- The idea is to propose and evaluate an intelligent control system (the Digital Twin) to showcase its added value in problem-solving.
  - We can justify its development (costs) in the future.
  - We already researched its design, capabilities, set-up and integration of AI methods.





Problem



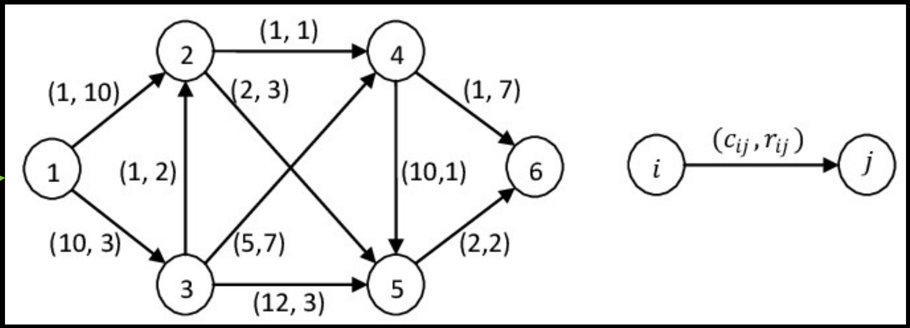
- Logistics Service Providers commonly solve the Vehicle Routing Problem to decide on the routing order of their customers on a daily basis.
  - NP-hard: In Mathematics, difficult to solve **exactly** in reasonable time with known algorithms

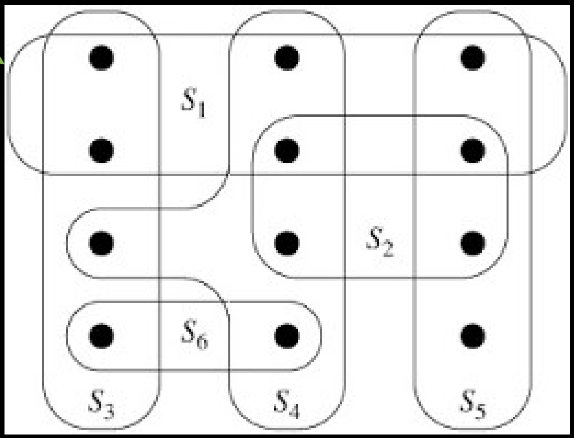
- Can we leverage Digital Twins to better solve VRP?
  - How can AI methods solve VRP?
  - How to integrate AI methods in Digital Twin?

PS: there is a million-dollar prize for a mathematical proof showing that whether (or not) it is possible to solve NP-hard problems **exactly** in reasonable time

Classical Method

1. Identify a set of promising routes
2. Select a final set of routes from promising routes.





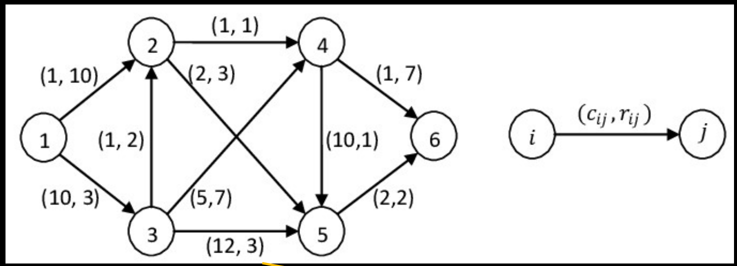
- Second part is easy and boils down to a simple selection problem.

- First part is where the challenge is.
  - Not so intuitive. How promising a route is depends on what other alternative routes are available.
  - A route ought to respect operational constraints associated with truck capacity, customer and depot time windows and possibly dynamic replanning

Identification of promising routes

- Mathematically, the problem is referred to as Elementary Shortest Path Problem with Resource Constraints and Time Windows (ESPRCTW):
  - Find a route starting and ending at the depot
  - Maximizes the overall usefulness by visiting customers most needed to be visited.
  - Take into account operational constraints.

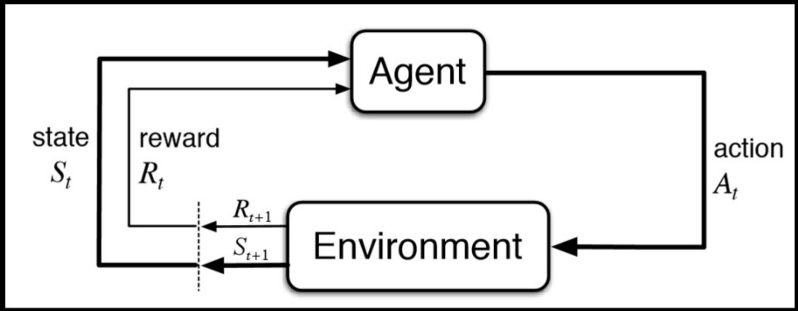
- ESPRCTW is NP-hard.
  - Explaining NP-hardness of VRP.
  - How can we solve it faster? Machine learning is a nominee.



Machine Learning for ESPRCTW

- Consider an extremely intelligent truck operator who must iteratively decide on the next customer to visit after each customer visit.
  - Can accurately compute the associated usefulness and inefficiency/wastage of visiting a customer next.
  - Keeping track of operational constraints.

- In machine learning terminology, this is a reinforcement-learning agent.
  - Produces an action, that transitions the environment to a new state and receives a reward accordingly.

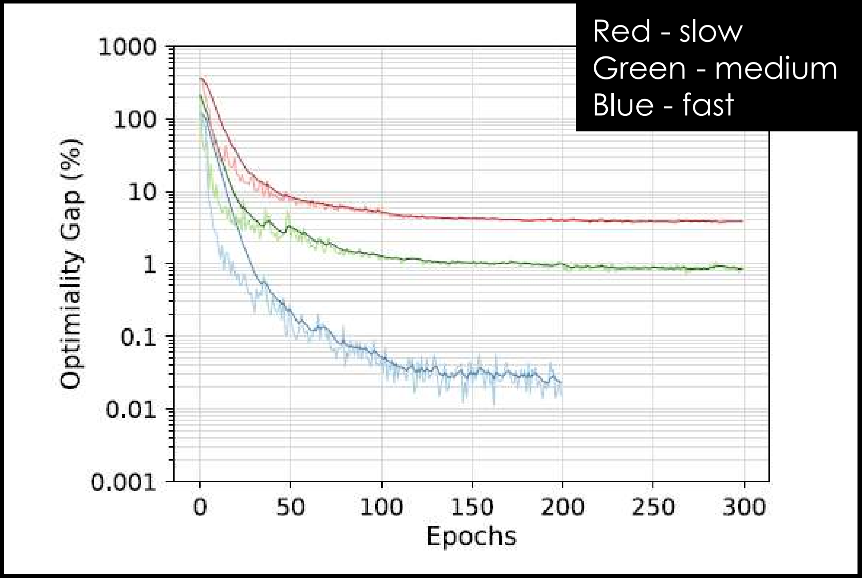


- Agent: route planner.
- Environment: network of customers to be served.
- Action: customer to visit next.
- State: info. on partially constructed route, remaining resources and customers yet to be feasibly served.
- Reward: gain of serving a customer.

Expected Outcome

- A model has been proposed and implemented.
  - Produces feasible routes.
  - Computational results are still pending

- Hopefully, the reinforcement learning agent will be able to solve ESPRCTW more efficiently.
  - Generate routes faster.
  - Solve VRP faster.



Thank You!!!