# Case Study: Optimizing Supply Planning Using Machine Learning

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# Overview

AI in the supply chain and route optimization

Case Study: Dynamic Vehicle Routing Problem

# AI in the Supply Chain and Route Optimization

# Benefits of AI in Supply Chain

**Estimating supply chain expenses**

**Lowering freight costs**

**Faster, more secure, more accurate supplier deliveries**

**Improved planning for participants in the supply chain**

# Vehicle Routing Problem (VRP)

**"What is the optimal set of routes for a fleet of vehicles to traverse in order to deliver to a given set of customers?"**

https://en.wikipedia.org/wiki/Vehicle_routing_problem

# Vehicle Routing Problem (VRP)

**NP-hard problem so commercial solvers often use heuristics to solve large-sized, real-world problems**

https://en.wikipedia.org/wiki/Vehicle_routing_problem

# Setting up the VRP

Delivery from one or more depots

Given a set of vehicles

Vehicles operated on a set of roads

Drivers drive on a road network to customers

# Setting up the VRP

**Determine a set of routes such that:**

All customer requirements and operational constraints satisfied

Global transportation cost minimized

# VRP Variants

**VRPP: Vehicle Routing Problem with Profits**

**VRPPD: Vehicle Routing Problem with Pickup and Delivery**

**VRPTW: Vehicle Routing Problem with Time Windows**

**CVRP: Capacitated Vehicle Routing Problem**

# Case Study: Dynamic Vehicle Routing Problem

# A Three-stage Algorithm for the Large Scale Dynamic Vehicle Routing Problem with Industry 4.0 Approach

# Background and Context

Dynamic large scale vehicle routing,
Industry 4.0, proposed solution overview

# Dynamic Vehicle Routing Problem (DVRP)

**Designing the optimal set of routes for a fleet of vehicles in order to serve a given set of customers while new customer orders arrive during the performance of the planned earlier work day.**

https://www.mdpi.com/2073-8994/11/4/546/htm

# Dynamic Vehicle Routing Problem (DVRP)

**Designing the optimal set of routes for a fleet of vehicles in order to serve a given set of customers** while new customer orders arrive during the performance of the planned earlier work day.

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# Dynamic Vehicle Routing Problem (DVRP)

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# Industry 4.0

**The fourth industrial revolution also known as “smart manufacturing”, “industrial internet”, “integrated industry”**

https://arxiv.org/pdf/2008.11719.pdf

# Industry 4.0

**Smart manufacturing network based on digitalization and automatization where machines and products interact with each other without any human involvement**

https://arxiv.org/pdf/2008.11719.pdf

# Industry 4.0 and DVRP

**Constant communication between systems:**

Supply chain management

Control tower

Depot

Drivers of vehicles

# Industry 4.0 and DVRP


Drivers can dynamically change or update their routes

GPS allows the control tower to know the current position of the driver

Can communicate next customer to visit

RFID chips and sensors in package facilitate this communication

# Vehicle Routing Problem (VRP)

**NP-hard problem so commercial solvers often use heuristics to solve large-sized, real-world problems**

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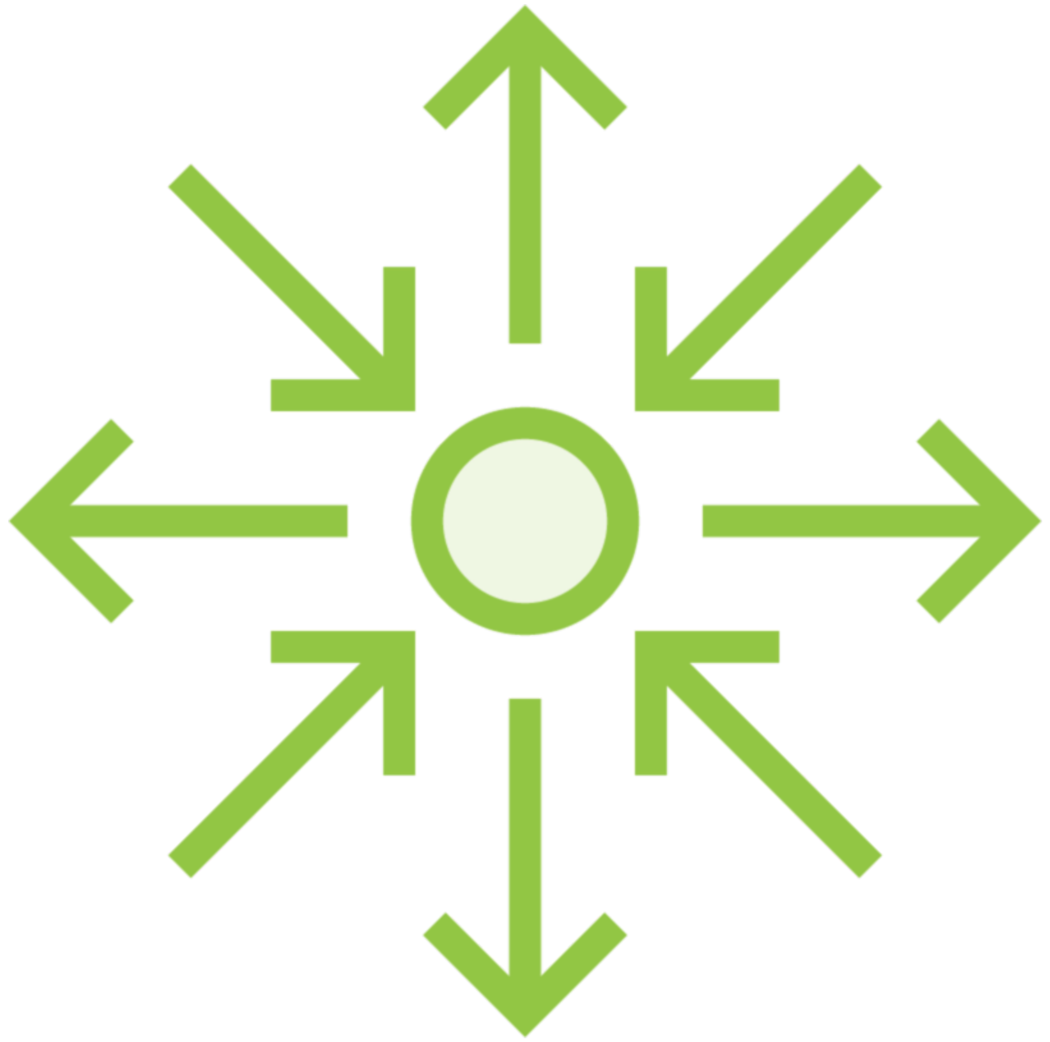
# Two Types of Heuristics

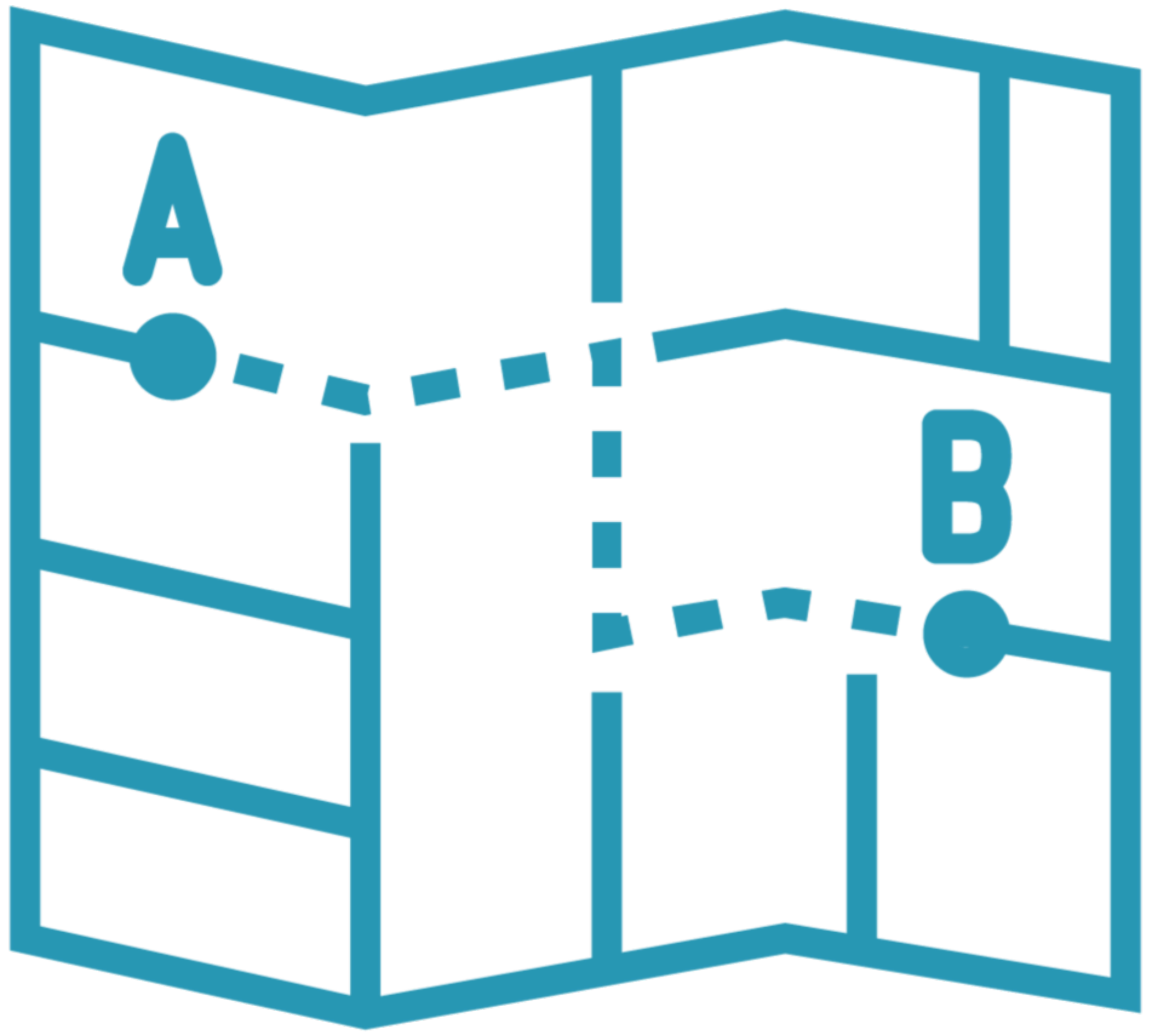
**Cluster first - route second**

**Route first - cluster second**

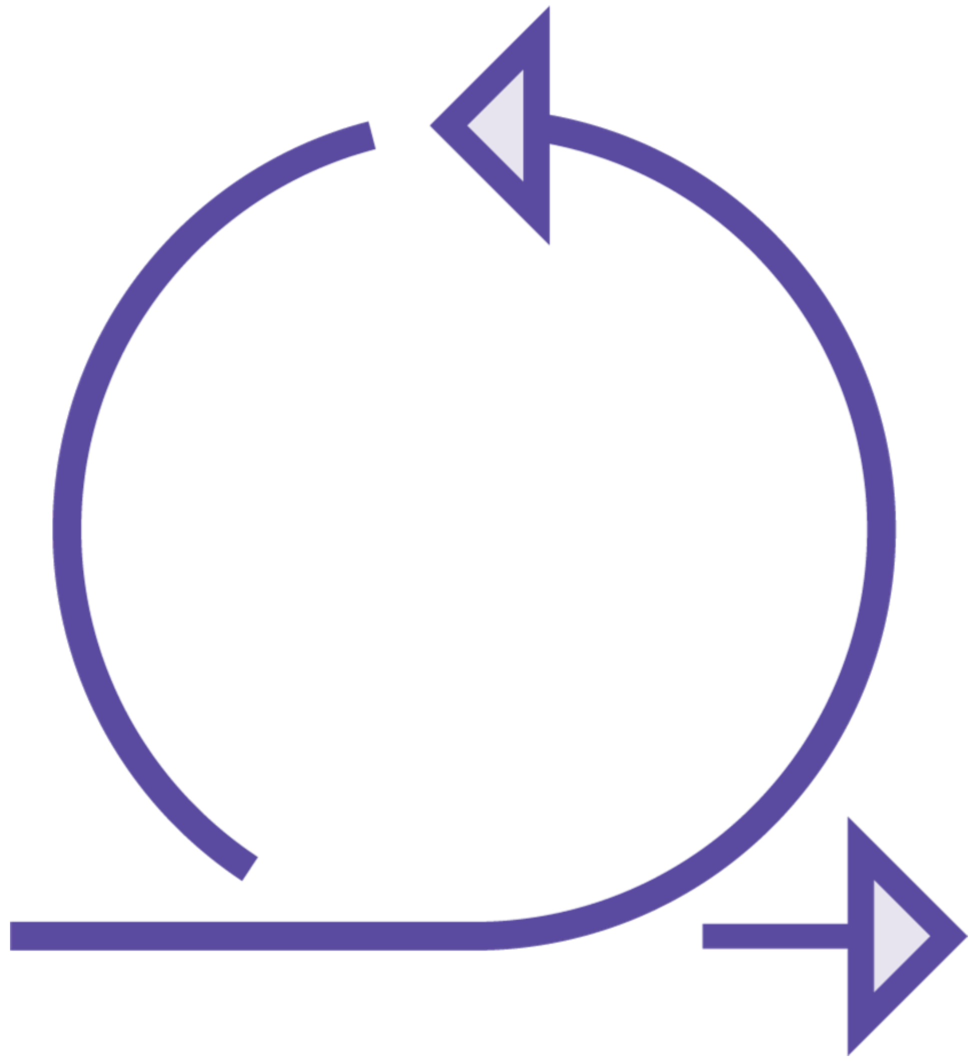
# Hierarchical Approach with Three Stages



**Cluster-first**

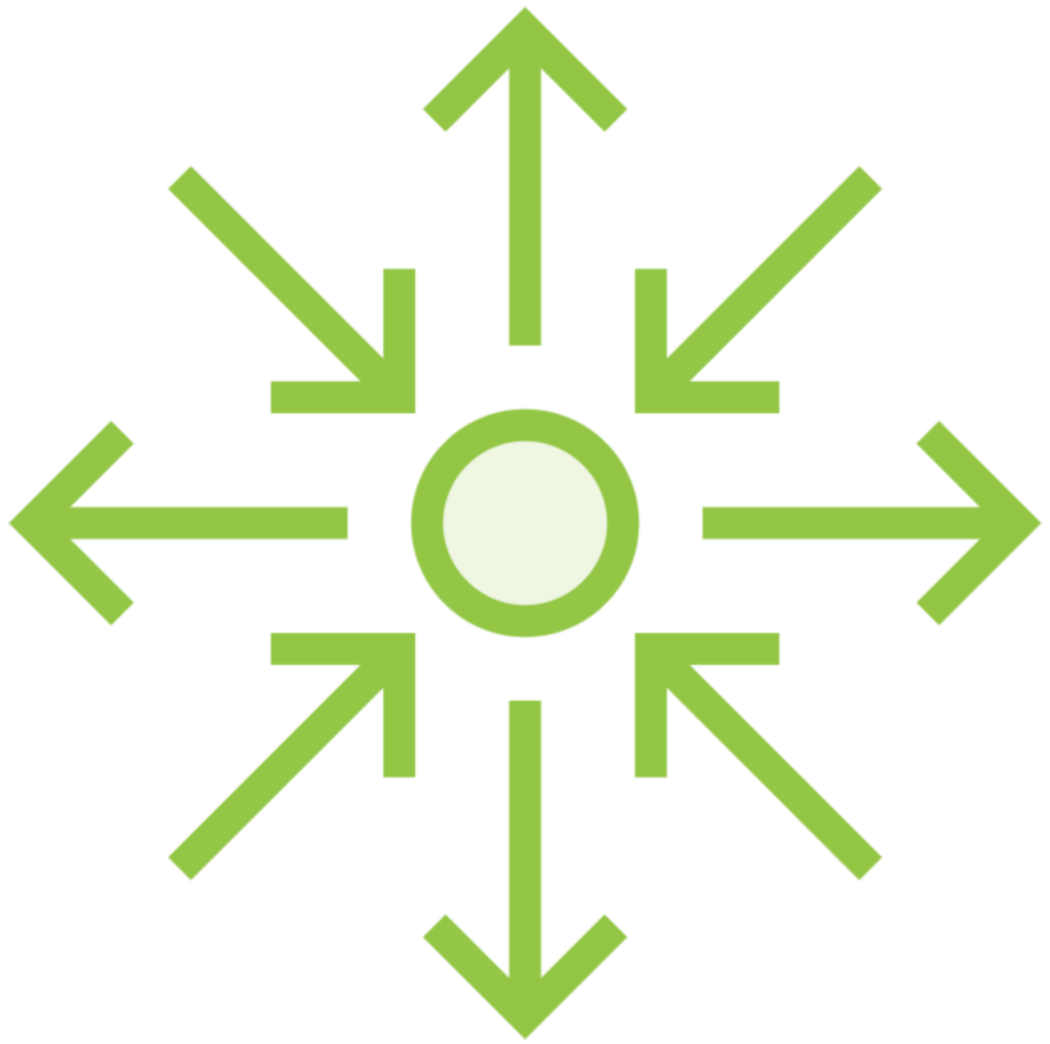



**Route-second**



**Route-improvement third**

# Hierarchical Approach with Three Stages



**Cluster-first**




Route-second



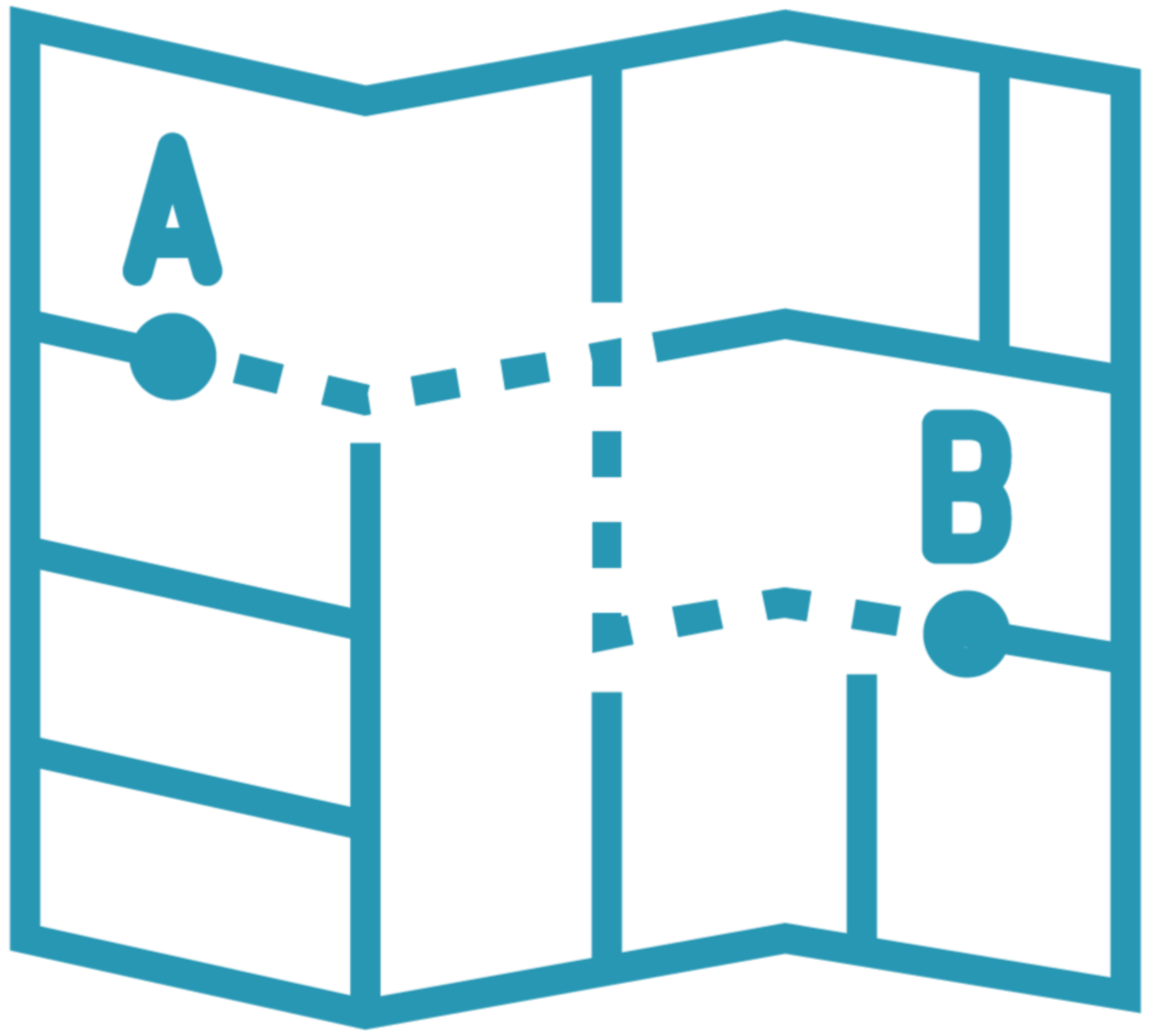
Route-improvement third

**Customers segmented using different clustering algorithms K-means, Gaussian Mixture Models, BIRCH**

# Hierarchical Approach with Three Stages



Cluster-first




**Route-second**



Route-improvement third

**Routing performed using construction algorithms such as Savings algorithm, Path Cheapest Arc algorithm**

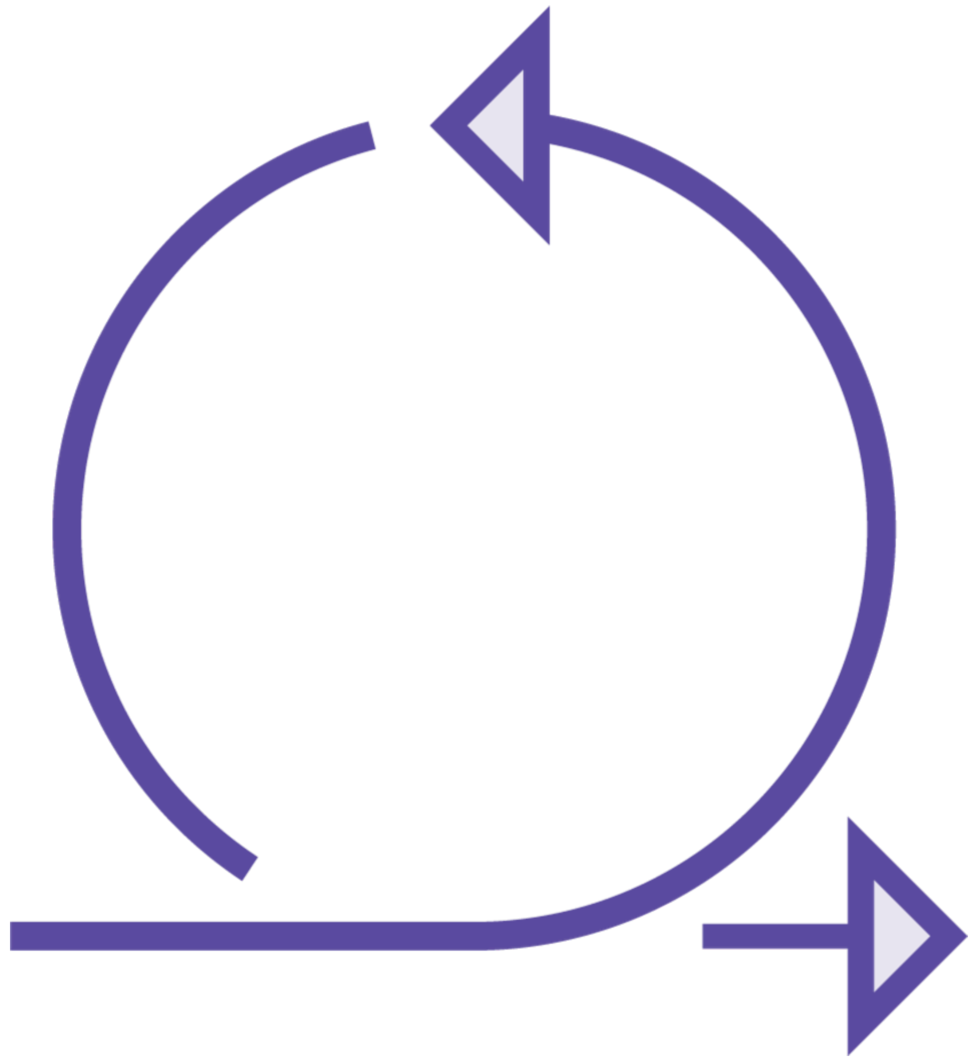
# Hierarchical Approach with Three Stages



Cluster-first




Route-second



**Route-improvement third**

**Apply improvement algorithms such as Guided Local Search, Simulated Annealing, Tabu Search**

# Problem Definition

Fixed number of vehicles with fixed capacity

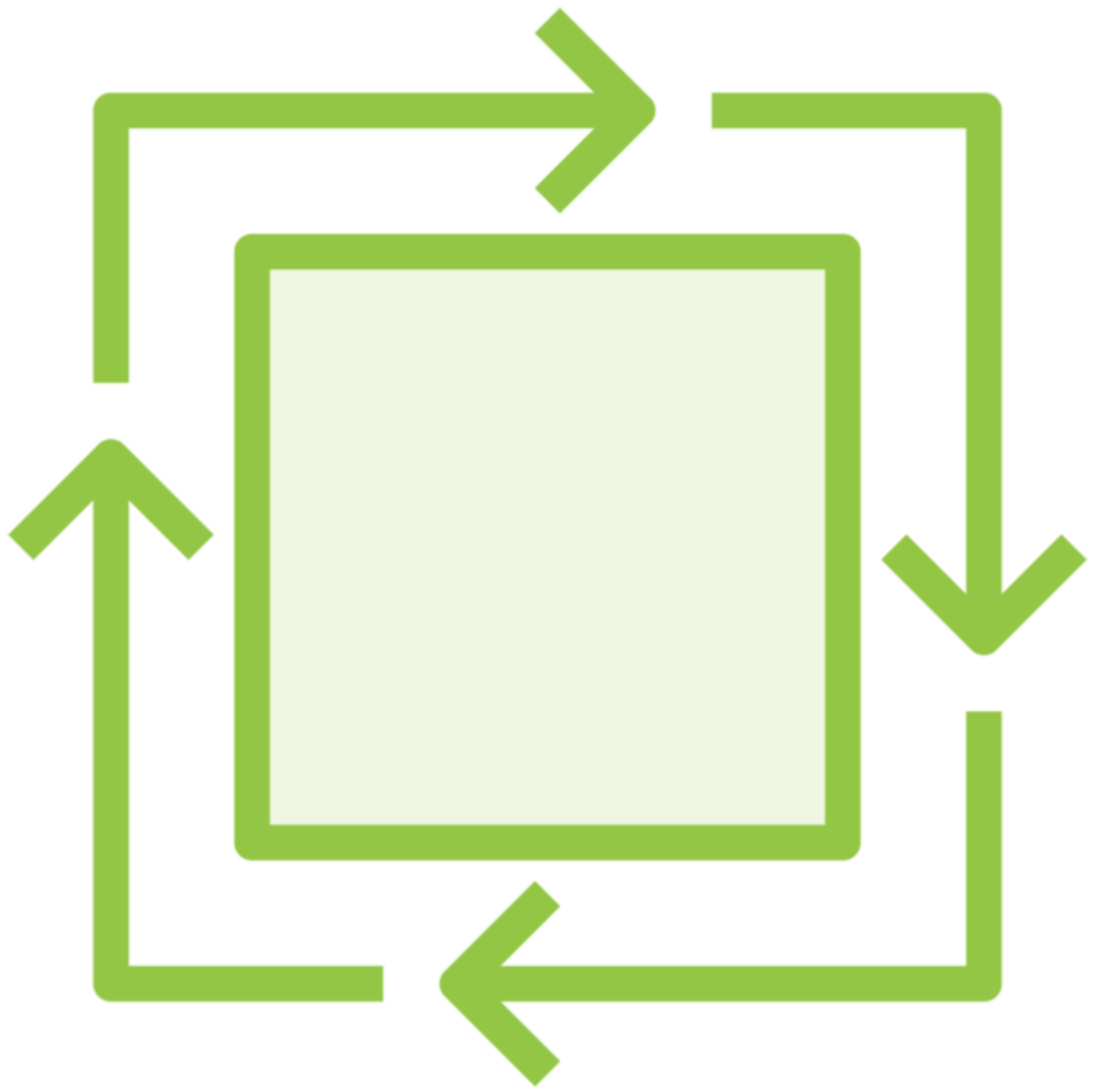
Depart from a depot

Deliver products to customers at demand points

New customers with known demand emerge over time

Distance assumed Euclidean distance

# Constraints



Vehicle starts and ends at depot

All customer demands accepted

Customer demands should be fully satisfied

Only one vehicle assigned to each route

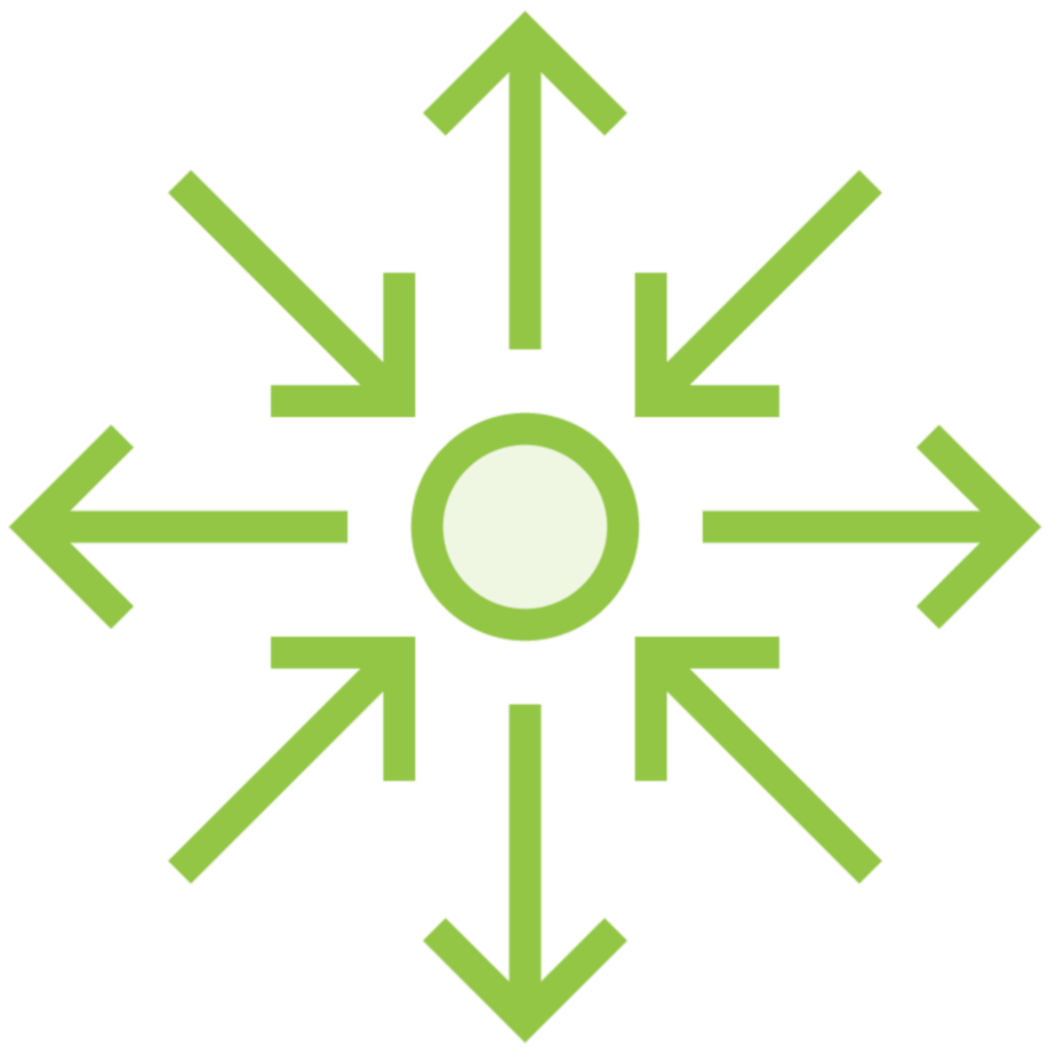
Sum of demands does not exceed vehicle's capacity

Cost of travel proportional to distance

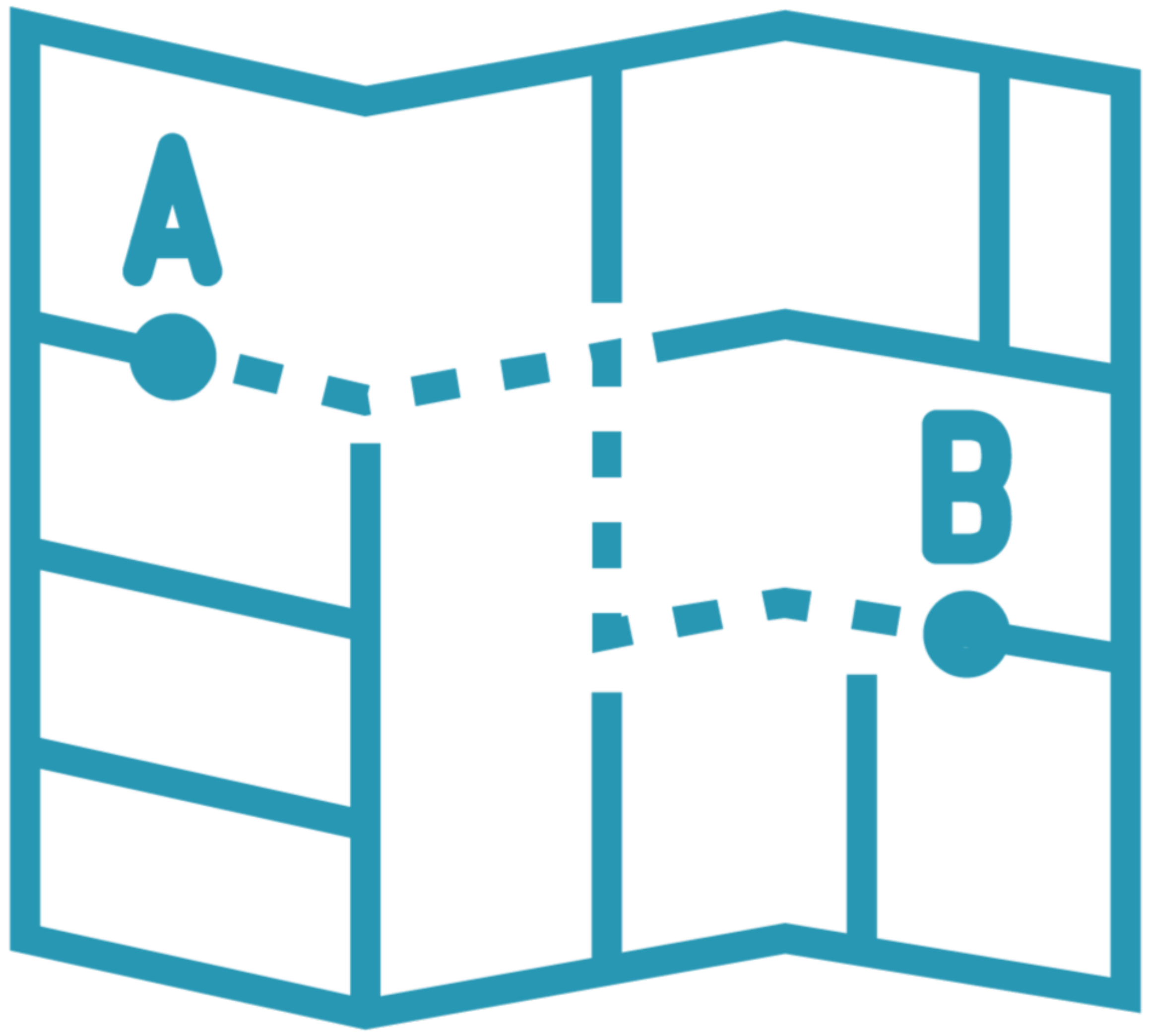
# Methodology and Results

Three stage algorithm and results

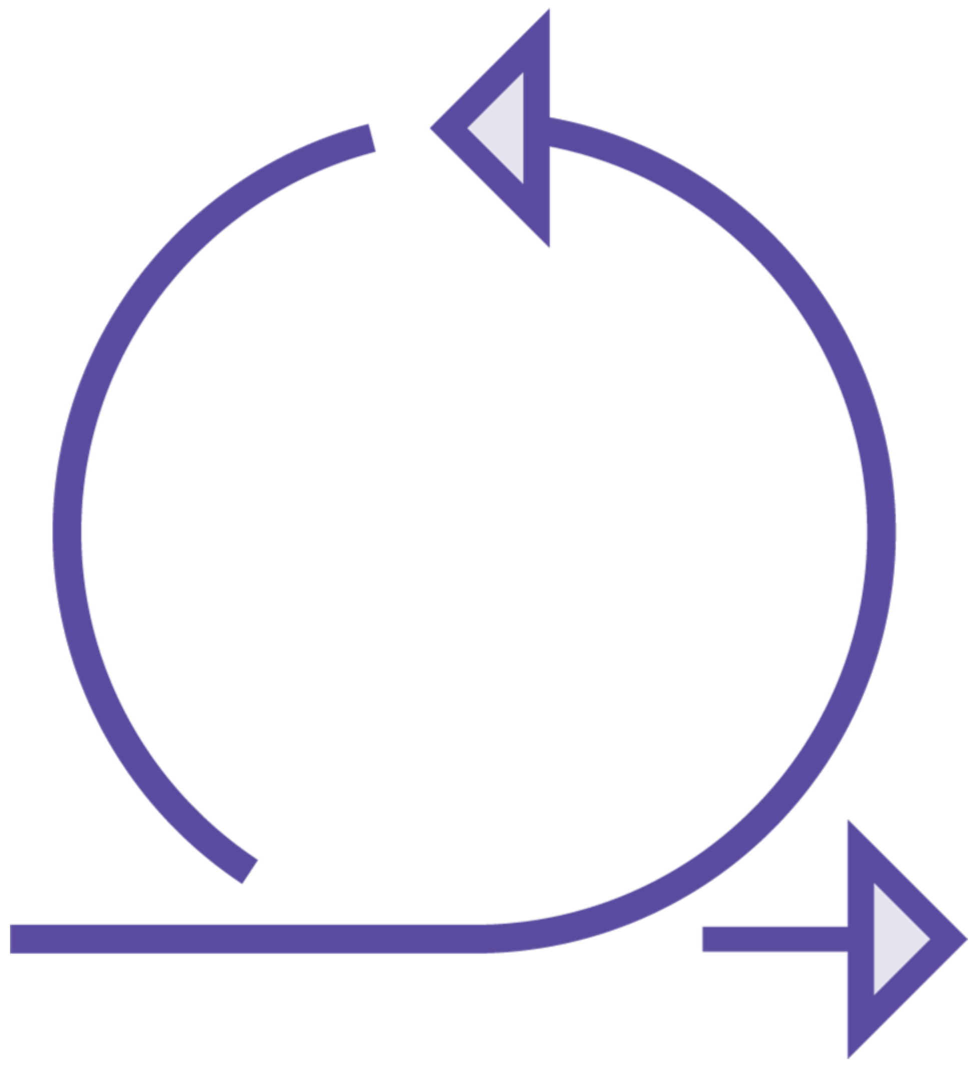
# Hierarchical Approach with Three Stages



**Cluster-first**




**Route-second**



**Route-improvement third**

# Three Stage Hierarchical Solution Workflow

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# Clustering

Unsupervised learning technique that separates data into groups

Find clusters with similar orders and similar geographic locations

First order clustering based on number of vehicles - refined to satisfy capacity of each vehicle

Find favorable clusters that satisfy capacity constraint - use K-means, GMMs, BIRCH

Feasible result from clustering algorithm fed into construction algorithm

# Construction

**Construct feasible route for each cluster separately**

**Objective function to minimize is total distance traveled**

**Use heuristic based algorithms such as Path Cheapest Arc, Savings, Global Cheapest Arc**

**Best route corresponds to shortest distance traveled**

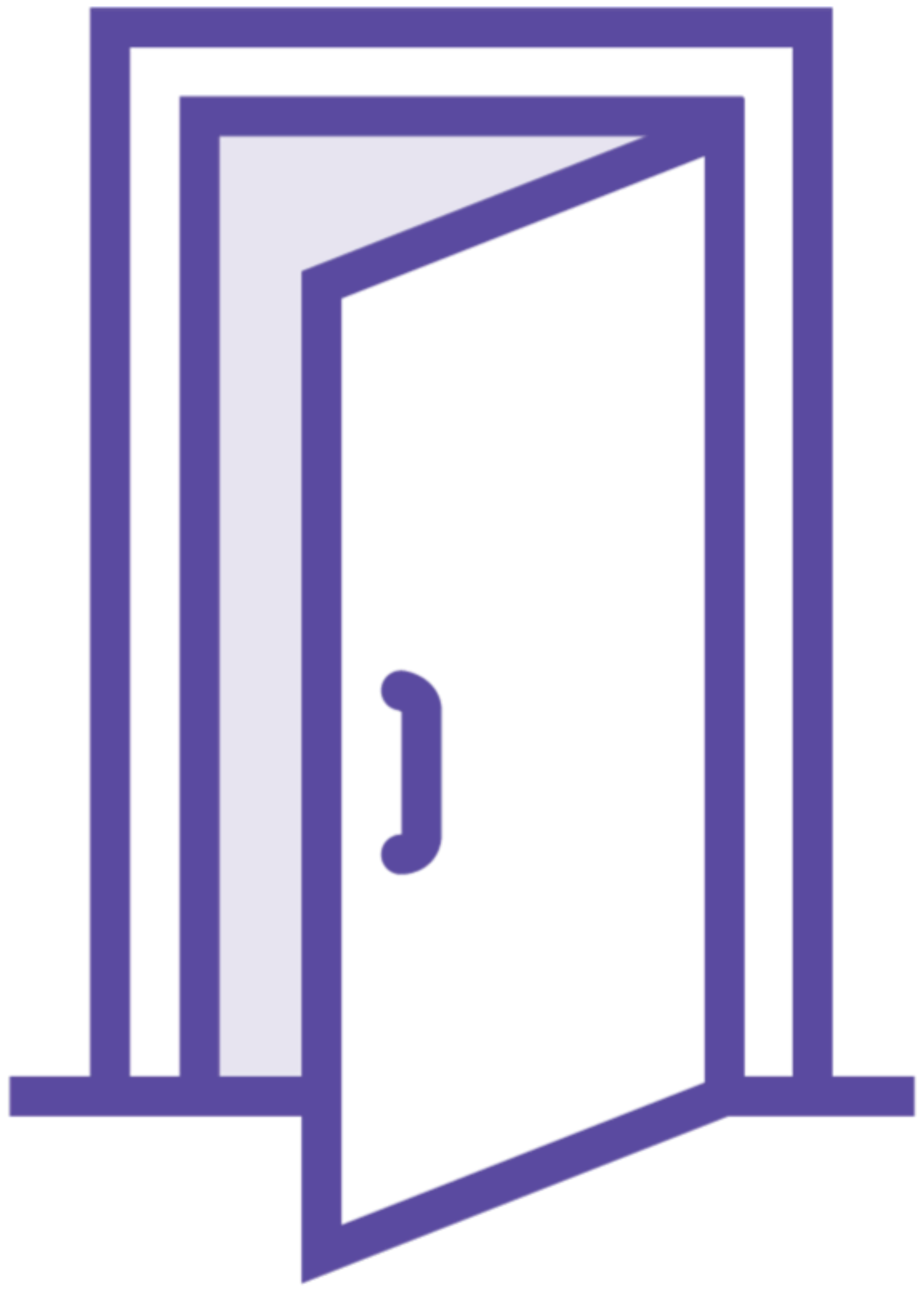
# Improvement

**Heuristic-based algorithms get a good solution in a reasonable amount of time - solution may not be optimal**

**Improvement algorithms help find better solutions - Guided Local Search, Simulated Annealing, Tabu Search**

**Exchanging or inserting may be done between and during routes - called “inter-route improvement”**

# New Customers



After executing the algorithm new customers may enter the system

Need to modify vehicle routes

Re-run the entire 3-stage algorithm

Customers already served removed from the system

Vehicle positions updated

Steps performed for each new customer

# Data Used

**Case study 1:**

Single depot

4 vehicles, capacity of 100

100 customers at t = 0

20 new customers enter randomly

# Data Used

**Case study 2:**

Single depot

4 vehicles, capacity of 125

100 customers at t = 0

100 new customers enter randomly

# Results

**Best results for case study 1:**

- K-means clustering
- Savings algorithm for construction
- Guided Local Search for route improvements

# Results

**Best results for case study 2:**

K-means clustering

Global Cheapest Arc algorithm for construction

Guided Local Search for route improvements

# Summary

**AI in the supply chain and route optimization**

**Case Study: Dynamic Vehicle Routing Problem**

# Up Next:
# Applying Machine Learning Techniques to Retail Data