Vehicle Routing & Scheduling

- Multiple Routes
- Construction Heuristics
  - Sweep
  - Nearest Neighbor, Nearest Insertion, Savings
  - Cluster Methods
- Improvement Heuristics
- Time Windows

Multiple Routes

- Capacitated VRP: vehicles have capacities.
  - Weight, Cubic feet, Floor space, Value.

- Deadlines force short routes.
  - Pickup at end of day.
  - Deliver in early morning.

- Time windows
  - Pickup.
  - Delivery.
  - Hard or Soft.

Multiple Route Solution Strategies

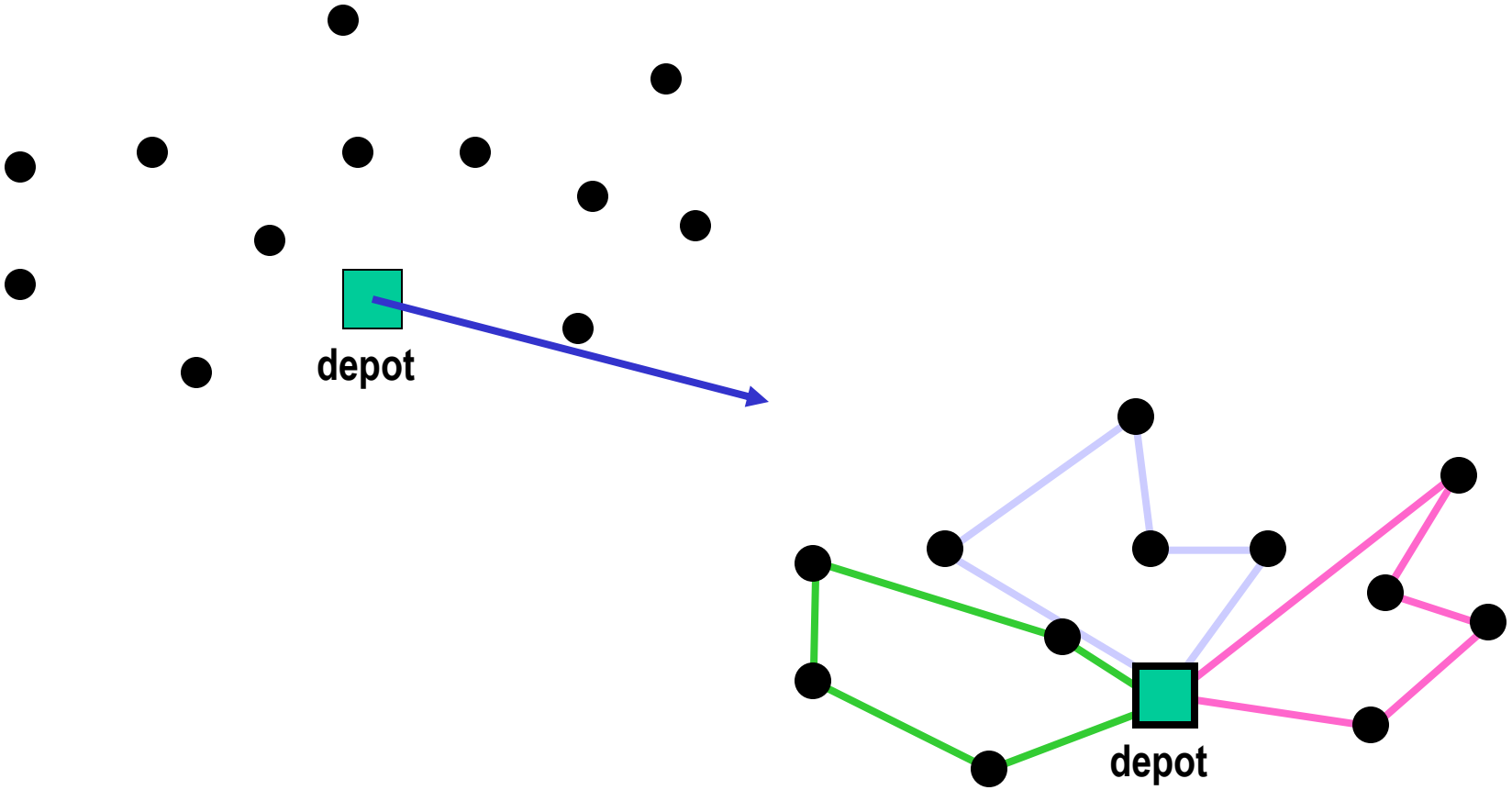
- Find feasible routes.
  - Cluster first, route second.
    - Cluster orders to satisfy capacities.
    - Create one route per cluster. (TSP for each cluster)
  - Route first, cluster second.
    - Create one route (TSP).
    - Break route into pieces satisfying capacities.
  - Build multiple routes simultaneously.
- Improve routes iteratively.

Sweep Algorithm

- Draw a ray starting from the depot.
- Sweep clockwise (or counter-clockwise) and add customers to the route as encountered.
- Start a new route when vehicle is full.
- Re-optimize each route (solve a TSP for customers in each route).

Sweep Algorithm

Suppose each vehicle capacity = 4 customers

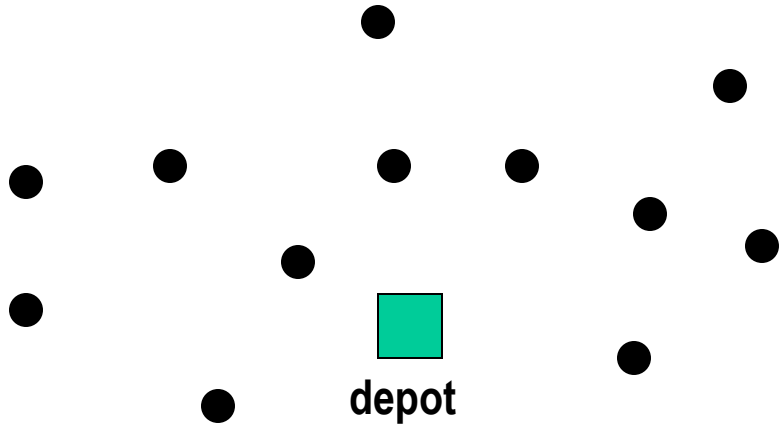


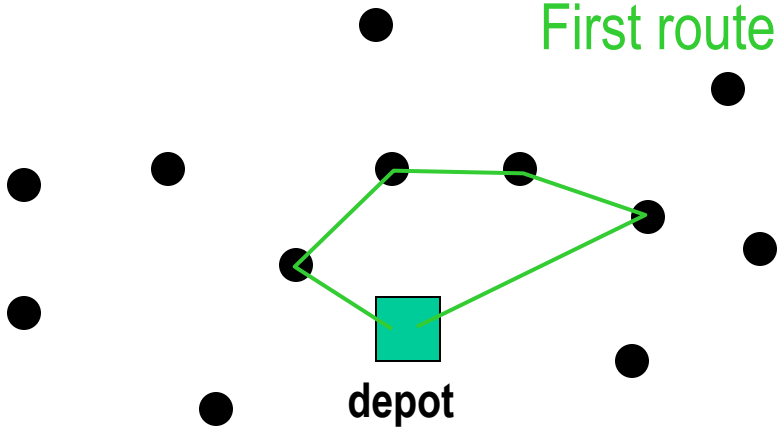
Nearest Neighbor, Nearest Insertion & Savings Algorithms

- Similar to for TSP, but keep track of demand on route.
- Start new route when vehicle is full.
- Re-optimize each route (solve a TSP for customers in each route).

Nearest Neighbor Algorithm

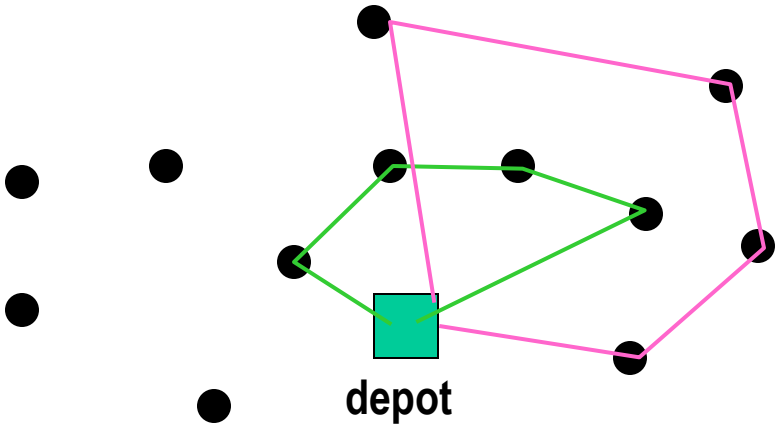
Suppose each vehicle capacity = 4 customers



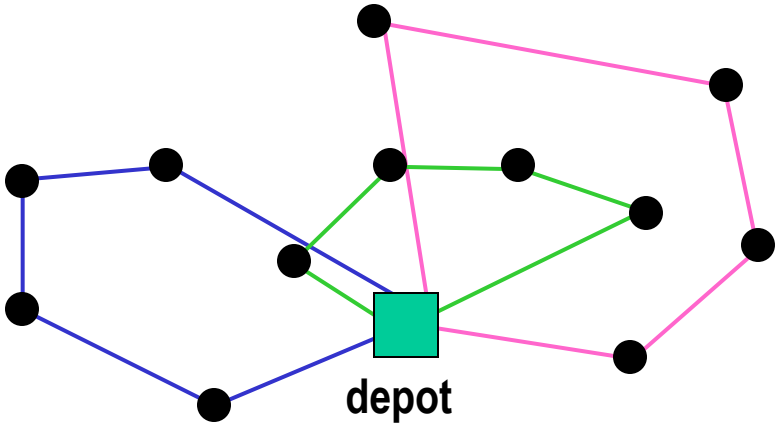


Nearest Neighbor Algorithm

Suppose each vehicle capacity = 4 customers



Second route



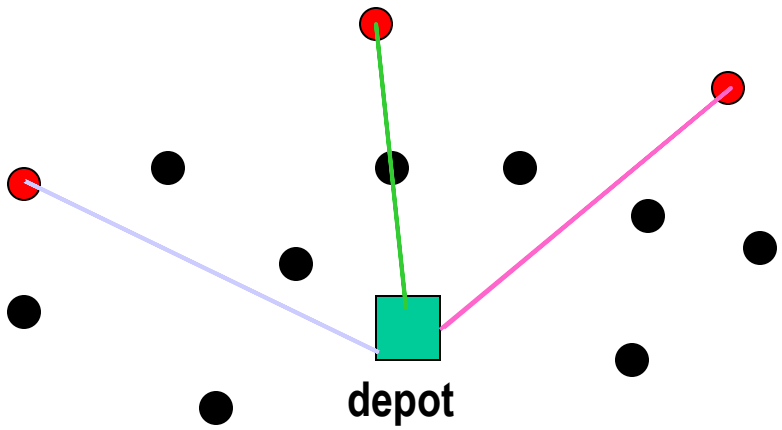
Third route

Cluster Algorithms

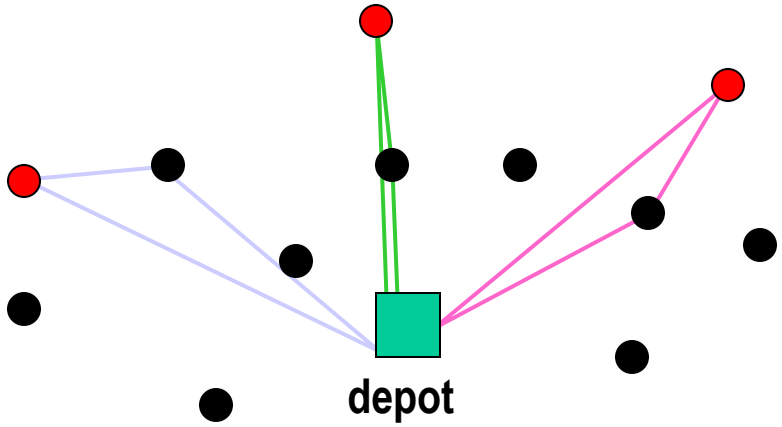
- Select certain customers as seed points for routes.
  - Farthest from depot.
  - Highest priority.
  - Equally spaced.
- Grow routes starting at seeds. Add customers:
  - Based on nearest neighbor or nearest insertion
  - Based on savings.
  - Based on minimum angle.
- Re-optimize each route (solve a TSP for customers in each route).

Cluster with Minimum Angle

Suppose each vehicle capacity = 4 customers



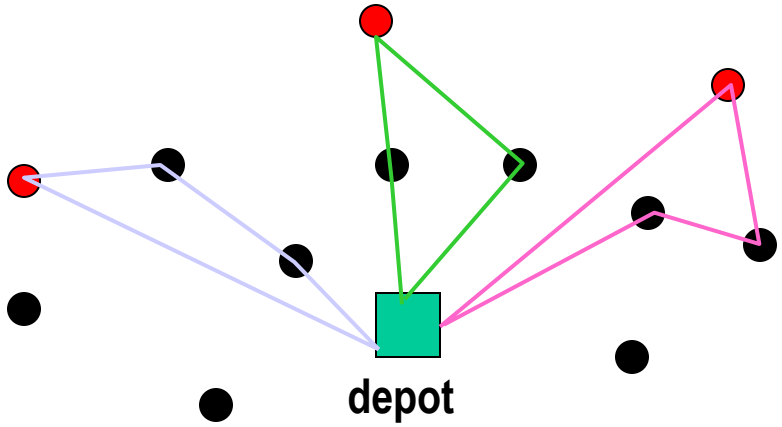
Select 3 seeds



Add customers with minimum angle

Cluster with Minimum Angle

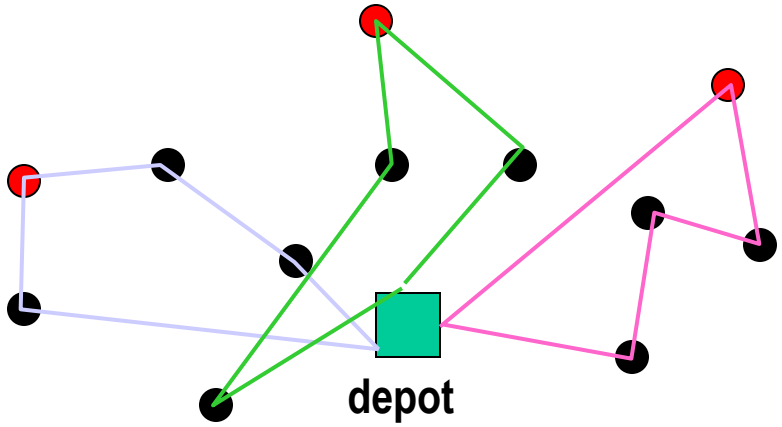
Suppose each vehicle capacity = 4 customers



Add customers with minimum angle

Cluster with Minimum Angle

Suppose each vehicle capacity = 4 customers



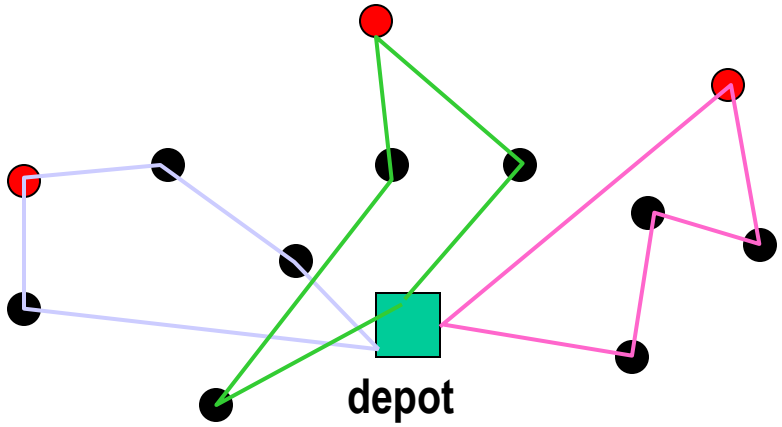
Add customers with minimum angle

VRP Improvement Heuristics

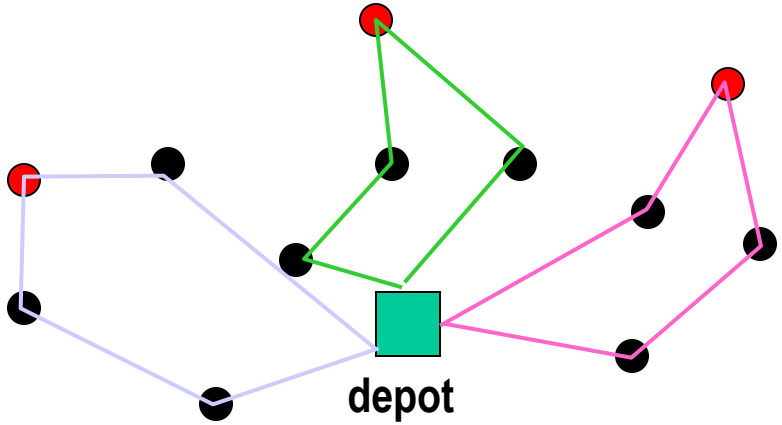
- Start with a feasible route.
- Exchange heuristics within a route.
  - Switch position of one customer in the route.
  - Switch 2 arcs in a route.
  - Switch 3 arcs in a route.
- Exchange heuristics between routes.
  - Move a customer from one route to another.
  - Switch two customers between routes.

Improvement Heuristics

Cluster with Minimum Angle



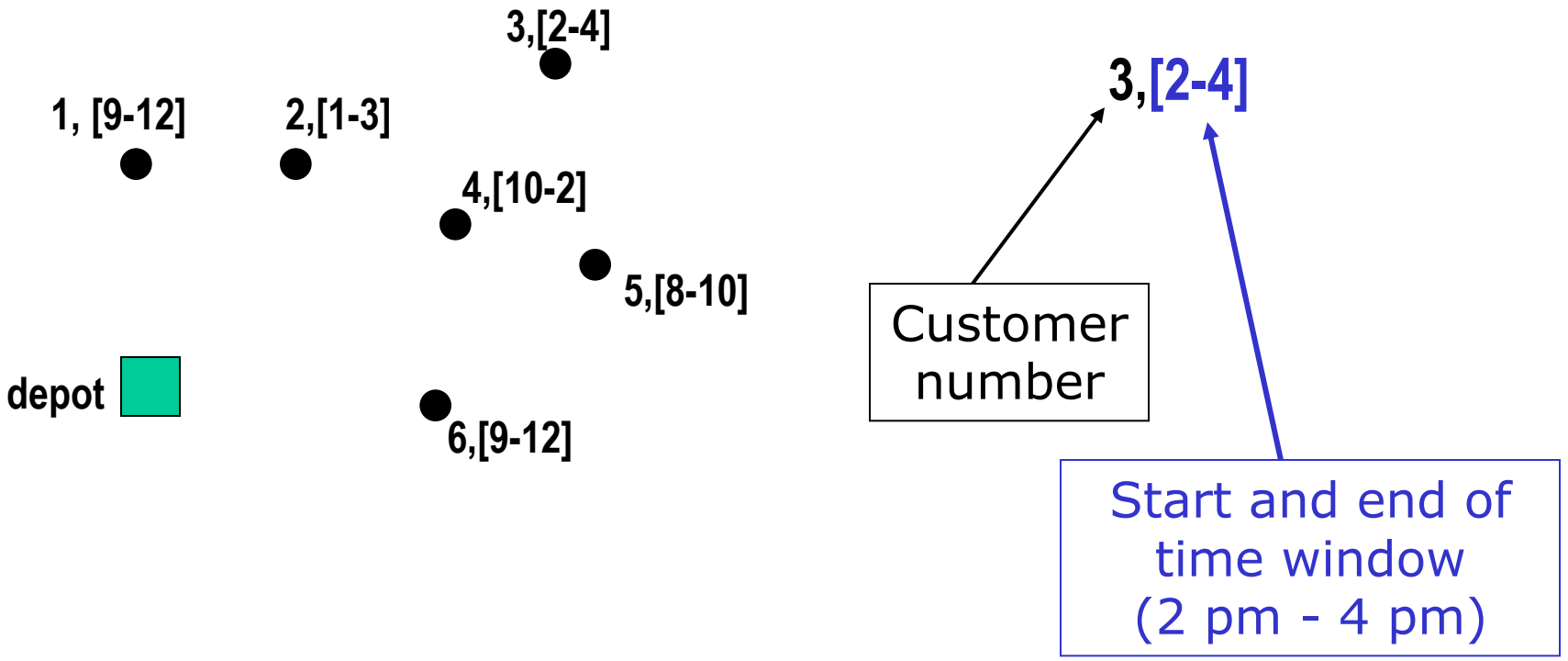
Starting routes



“Optimized” routes

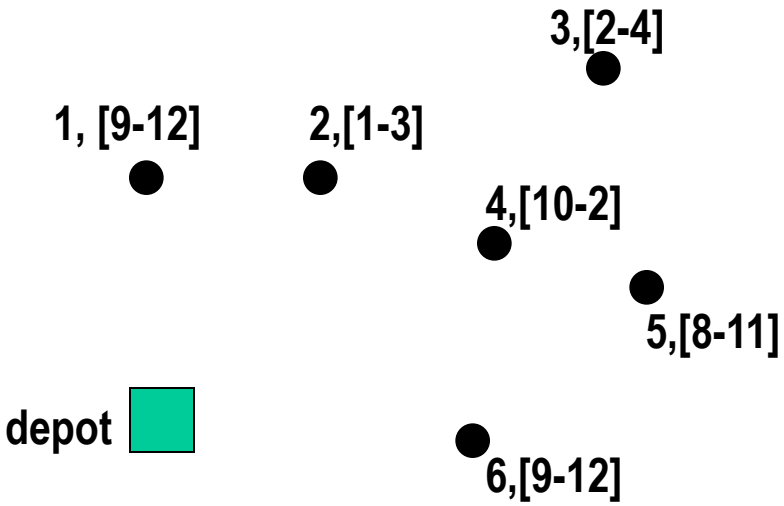
Time Windows

- Problems with time windows involve routing and scheduling.



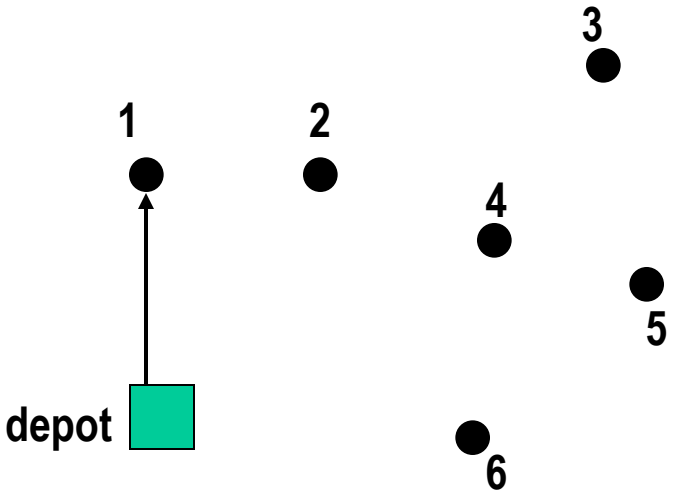
Routing Example with Time Windows

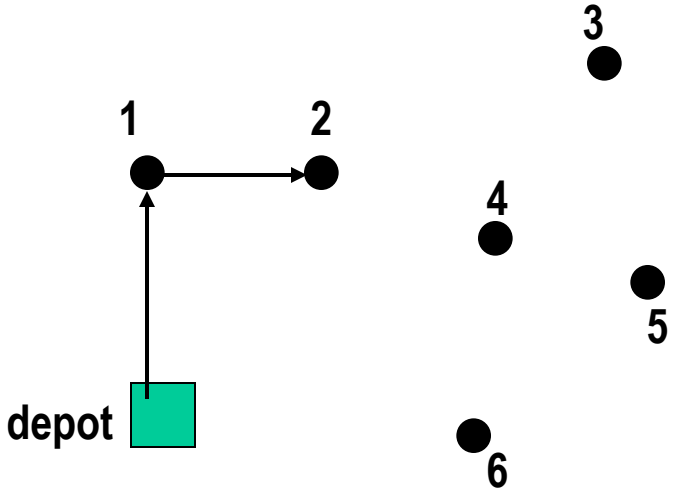
One hour travel time between any two customers.
Half hour delivery time at each customer.



Nearest Insertion - No Time Windows

Insert nearest customer to route in best location.





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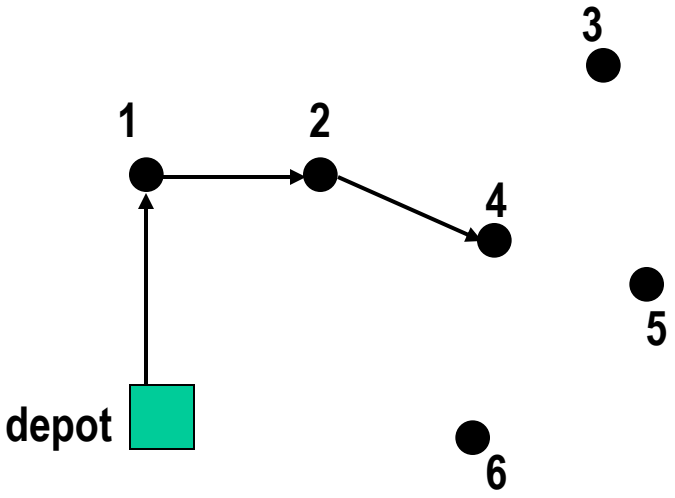

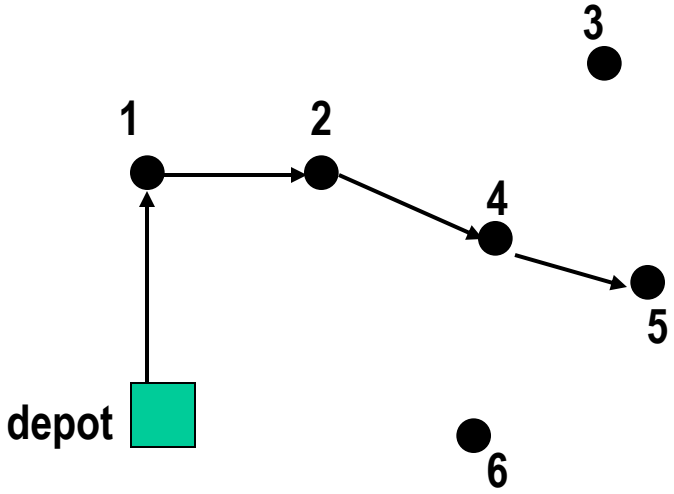

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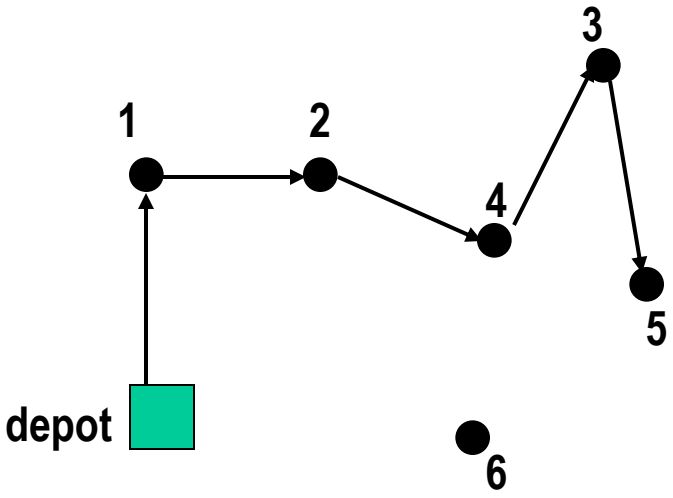
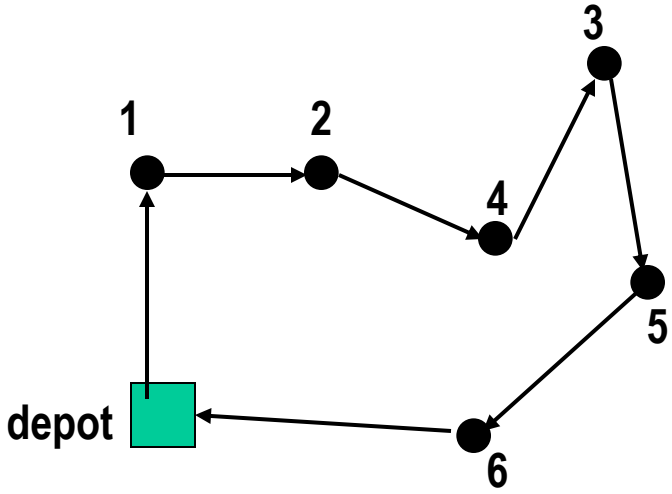
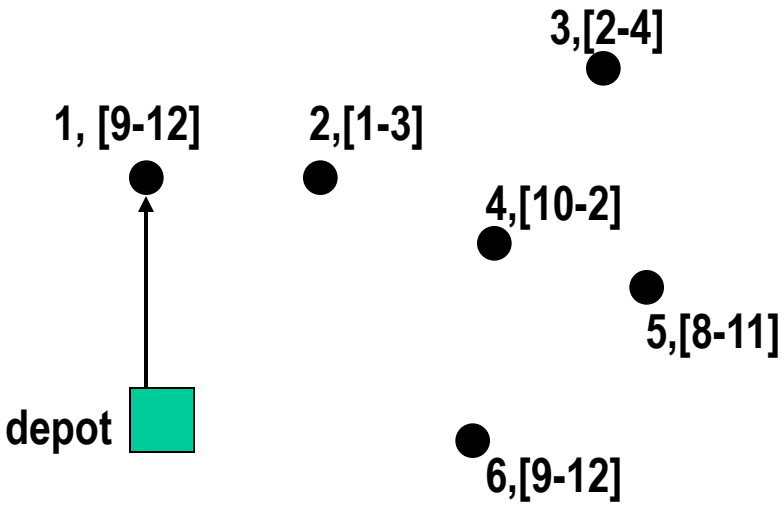




Nearest Insertion with Time Windows

One hour travel time between any two customers.
Half hour delivery time at each customer.

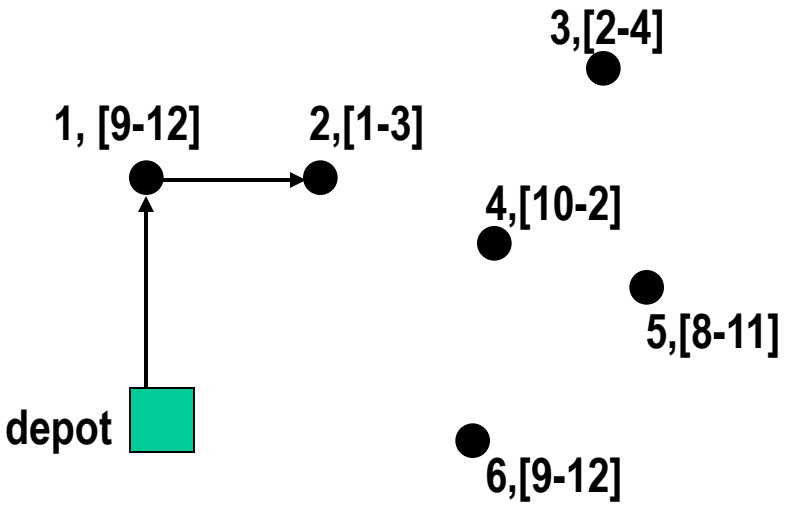


Leave depot: 8:00 - 11:00
Arrive at 1: 9:00 - 12:00
Leave 1: 9:30 - 12:30

depot-1

Nearest Insertion with Time Windows

One hour travel time between any two customers.
Half hour delivery time at each customer.

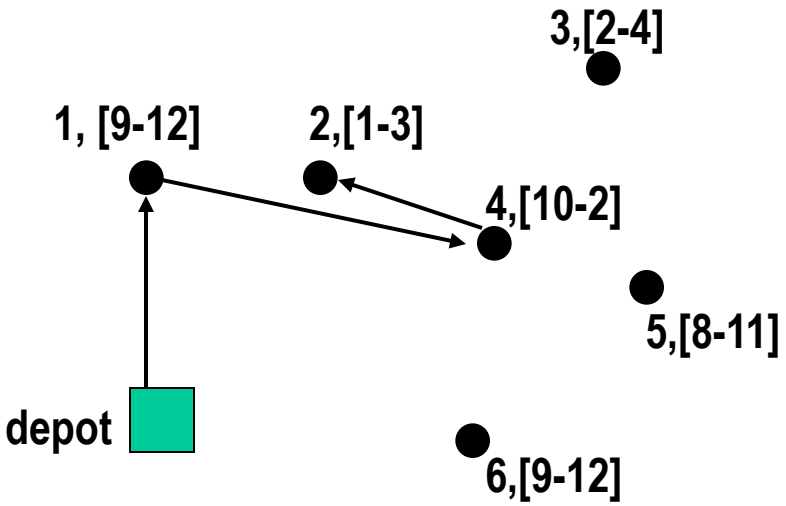


Leave depot:	10:30
Arrive at 1:	11:30
Leave 1:	12:00
Arrive at 2:	1:00
Leave 2:	1:30

depot-1-2

Nearest Insertion with Time Windows

One hour travel time between any two customers.
Half hour delivery time at each customer.

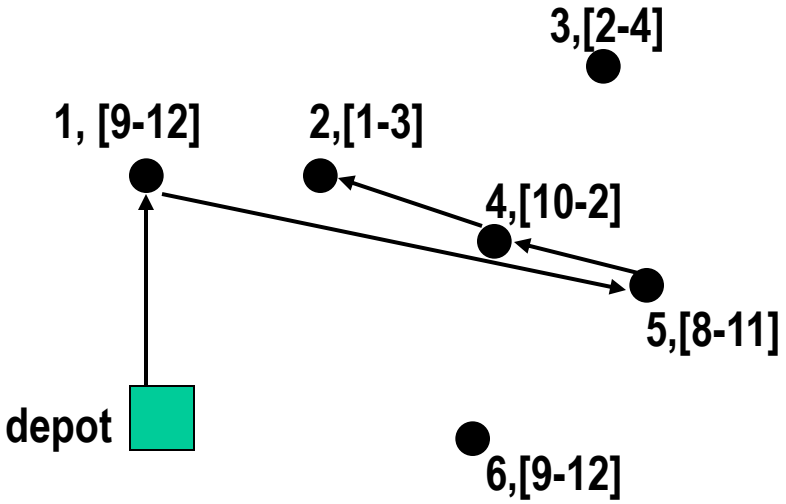


Leave depot:	9:00
Arrive at 1:	10:00
Leave 1:	10:30
Arrive at 4:	11:30
Leave 4:	12:00
Arrive at 2:	1:00
Leave 2:	1:30

depot-1-4-2

Nearest Insertion with Time Windows - one option

One hour travel time between any two customers.
Half hour delivery time at each customer.

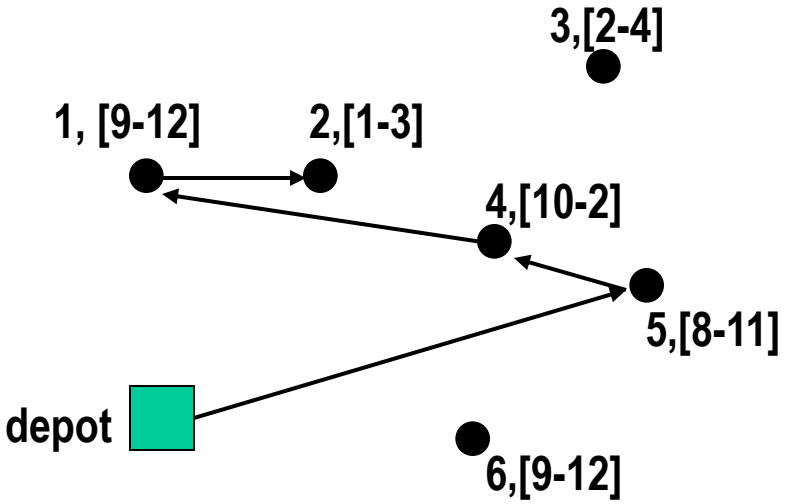


Leave depot:	8:00
Arrive at 1:	9:00
Leave 1:	9:30
Arrive at 5:	10:30
Leave 5:	11:00
Arrive at 4:	12:00
Leave 4:	12:30
Arrive at 2:	1:30
Leave 2:	2:00

depot-1-5-4-2

Nearest Insertion with Time Windows - a better option

One hour travel time between any two customers.
Half hour delivery time at each customer.

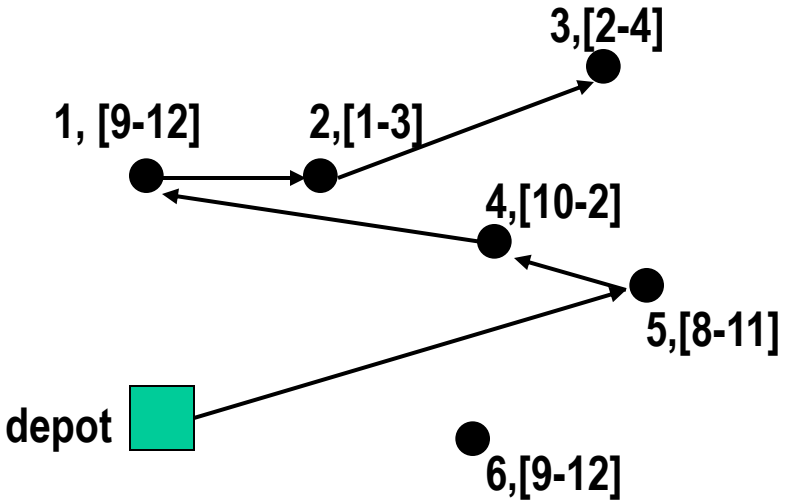


Leave depot:	7:30
Arrive at 5:	8:30
Leave 5:	9:00
Arrive at 4:	10:00
Leave 4:	10:30
Arrive at 1:	11:30
Leave 1:	12:00
Arrive at 2:	1:00
Leave 2:	1:30

depot-5-4-1-2

Nearest Insertion with Time Windows

One hour travel time between any two customers.
Half hour delivery time at each customer.

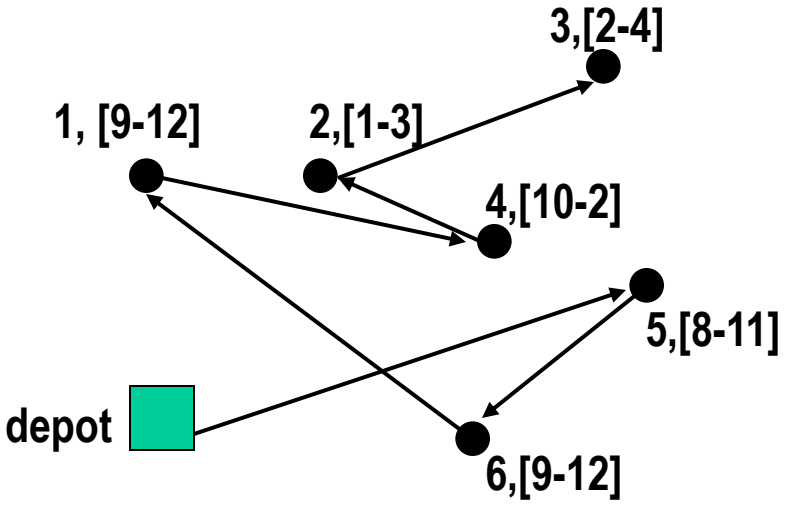


Leave depot:	7:30
Arrive at 5:	8:30
Leave 5:	9:00
Arrive at 4:	10:00
Leave 4:	10:30
Arrive at 1:	11:30
Leave 1:	12:00
Arrive at 2:	1:00
Leave 2:	1:30
Arrive at 3:	2:30
Leave 3:	3:30

depot-5-4-1-2-3

Nearest Insertion with Time Windows

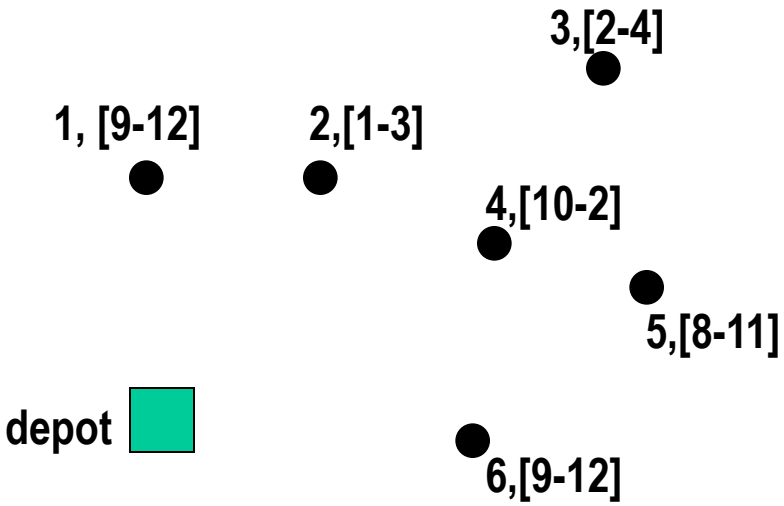
One hour travel time between any two customers.
Half hour delivery time at each customer.



Leave depot:	7:00
Arrive at 5:	8:00
Leave 5:	8:30
Arrive at 6:	9:30
Leave 6:	10:00
Arrive at 1:	11:00
Leave 1:	11:30
Arrive at 4:	12:30
Leave 4:	1:00
Arrive at 2:	2:00
Leave 2:	2:30
Arrive at 3:	3:30

depot-5-6-1-4-2-3

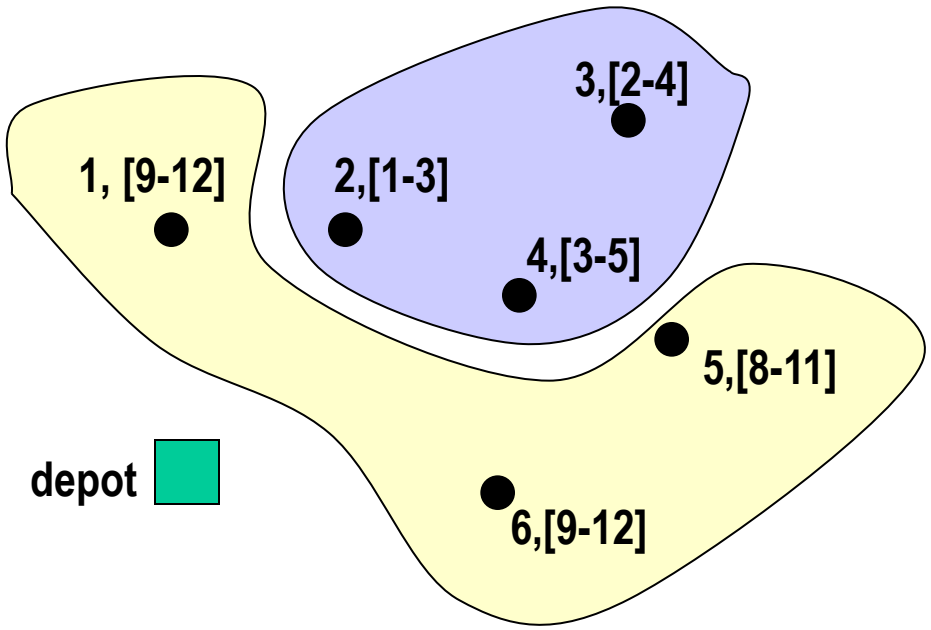
Routing with Time Windows



Route must be built with both time windows & geography in mind!

Clustering and Time Windows

- Cluster customers based on location and time window.
- Design routes for each cluster.



Clustering and Time Windows

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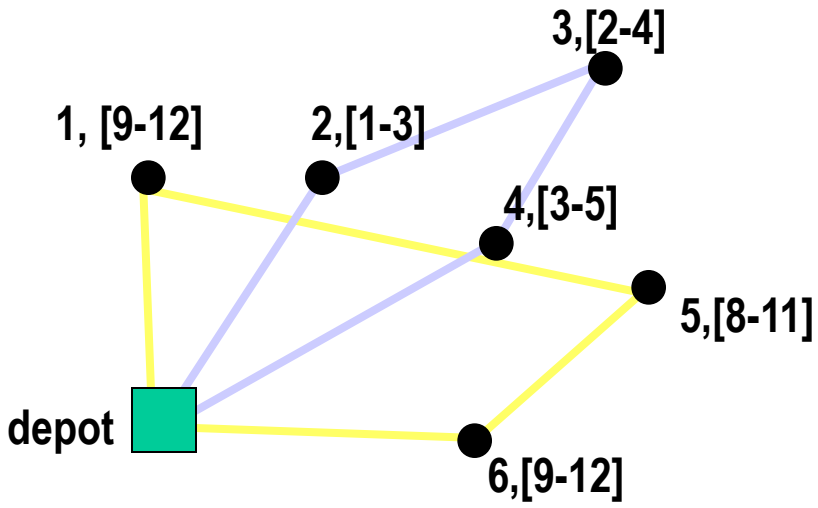


ArcLogistics Route Solution Technique

- Construct travel time (distance) matrix.
  - Shortest paths on actual (GIS) road network.
- Build initial routes by inserting orders on routes.
  - Can not exceed vehicle capacities, precedence rules, skill set constraints (specialties).
  - Can violate time windows and route duration.
- Improve routes.
  - Within route improvements.
  - Between route improvements.

ArcLogistics Route Insertions

- Objective: Minimize weighted sum of:
  - travel times *(t),*
  - time window violations *(v),* and
  - free (waiting) time *(w).*

$$\sum_r \alpha_1 t_r + \alpha_2 v_r + \alpha_3 w_r$$

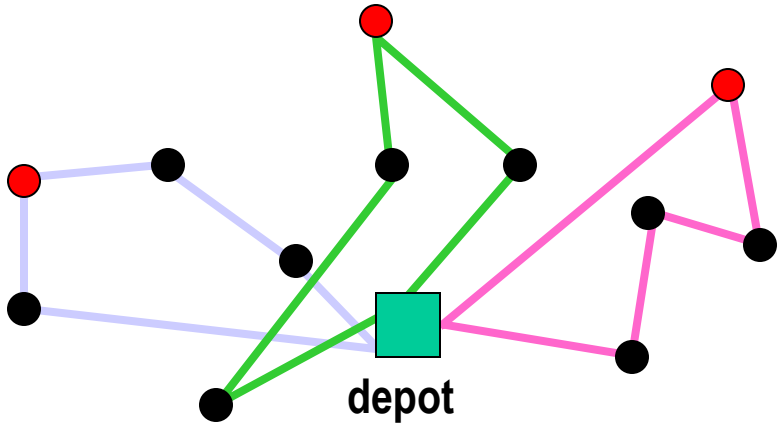
- User sets weights α_1, α_2, α_3 via slider bar in "Rate the importance of meeting time windows".
  - Lowest value = 0 is for lowest cost
  - Highest value = 10 is for most importance on meeting time windows.

ArcLogistics Route Improvements

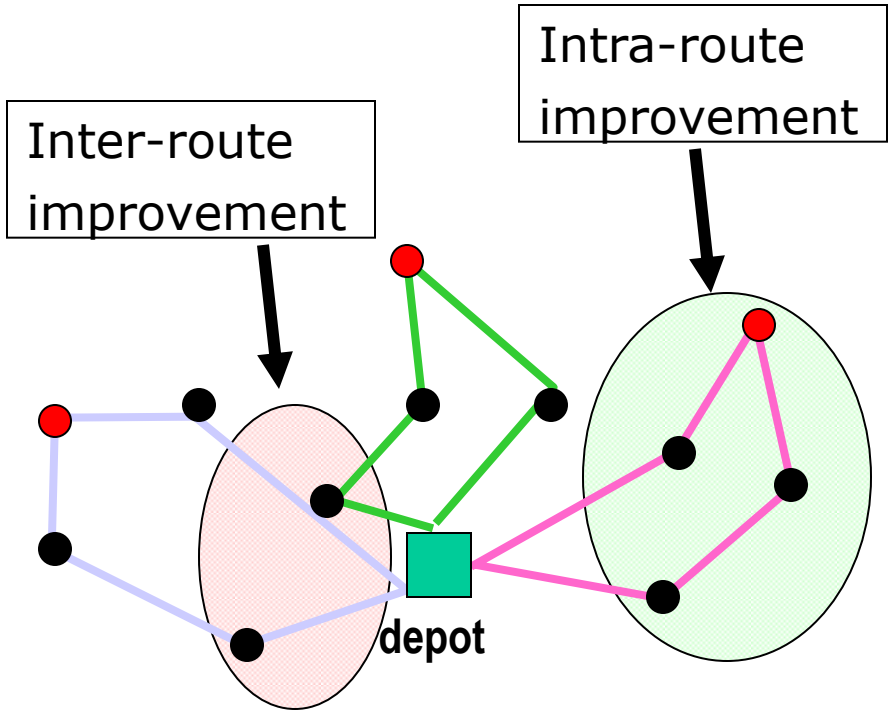
- Within route (intra-route) improvements.
  - Maintain stops on each route.
  - Consider each route separately.
  - Find best position for each stop on each route.

- Between route (inter-route) improvements.
  - Transfer or switch: Move one stop from one route to another.
  - Exchange: Exchange two stops between two routes.

Improvement Heuristics



Starting routes



"Improved" routes

Modeling Details

- Road network.
  - How detailed is the road network?
  - Affects distance and cost calculations.
- Geocoding.
  - Where are addresses located?
- Linking locations to road network.
  - How do vehicles get from locations to road nework?

Road Network Detail

- Models should measure travel distance, time and cost on actual road network.
- More detailed road networks mean:
  - More accurate cost, distance and travel time.
  - Slower solutions.
  - Longer time to set up data.
  - Larger data files.
- What is purpose?
  - Operational: To provide detailed driving directions?
  - Strategic: To estimate costs, times, and routes?

Road Network Detail

- How are speeds specified?
  - Different types of roads have different speeds.
  - Hard to include time varying speeds.
- Showing every road may be unrealistic.
  - Large trucks may not use small local roads.
- Road network changes over time.
  - Example: new residential areas.
  - Are customers in older, established areas or newer suburbs?

Geocoding

- Finding geographic locations from addresses.
- Depending on scale of problem, may geocode at various levels.
- Zip codes.
  - Geocode to a point at center of zip code.
  - Zip codes are defined with boundaries and centroids.
- Cities.
  - Geocode to a point representing city location.

Geocoding - Street Addresses

- Street addresses
  - Each road segment has associated address ranges on each side.
  - Address is interpolated between start and end of address range.
  - Assumes even spacing of addresses.

- Example:
  - Main Street, left side: 300-498, right side 301-499
  - 420 E. Main Street is about 60% of the way down the road segment on the left side.

Address Matching

- Can be very complicated.
- Only part of address may match.
  - Street name, city and zip code match; address range doesn't.
  - Street name and city match; zip code doesn't.
- Part of address may be incorrect.
  - Missing prefix (East).
  - Incorrect suffix (Street vs. Boulevard).
  - Name may be abbreviated in database (Ave for Avenue or Avenida).
  - Zip code may be wrong.

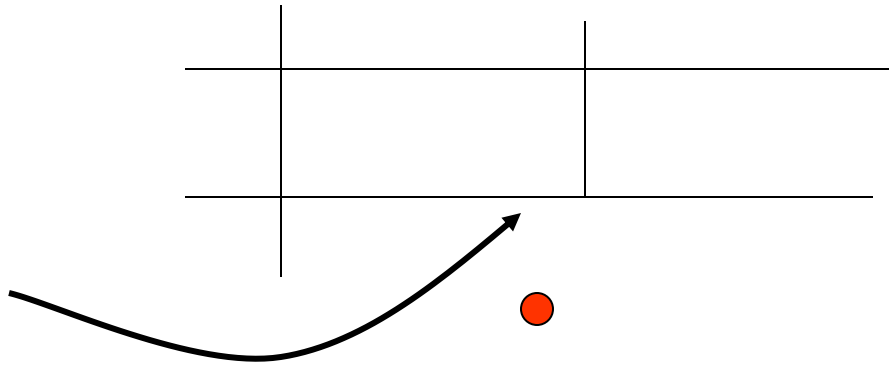
Address Matching

- Streets may have several names.
  - Highway 67 is also Lindbergh Blvd.
- Streets change names, especially at city boundaries.
  - Lindbergh, Highway 67, Kirkwood Road.
  - Olive Boulevard, Olive Street, Olive Street Road, Old Olive Street Road.
- New streets are added and old streets are renamed.

Linking Locations to Road Network

- User may specify locations not on streets.
  - User Pick in ArcLogistics Route.
- How should this be linked to street network?

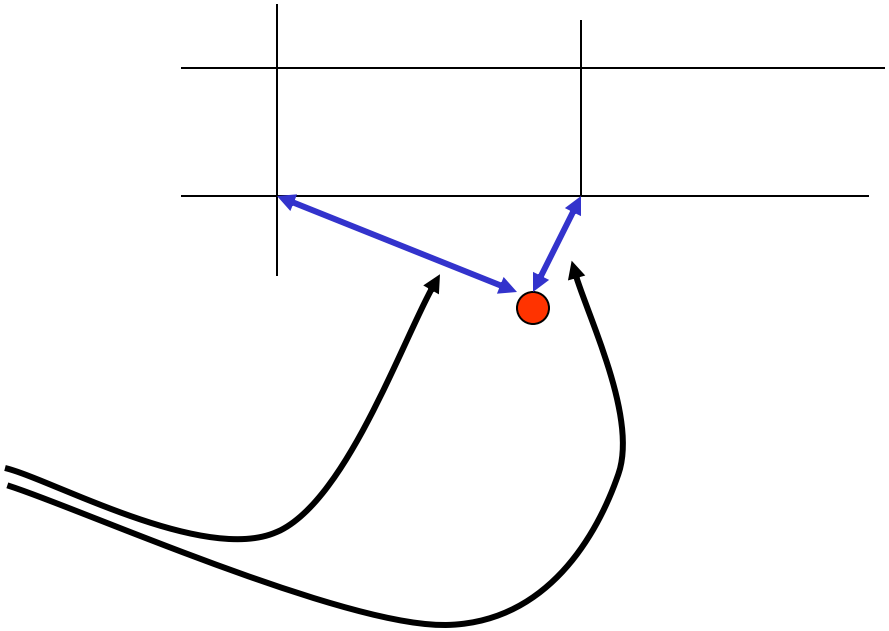
- ArcLogistics Route forces locations not on streets to be on nearest street.



ArcLogistics Route assumes locations is here

Linking Locations to Road Network

- Other packages assume straight line travel from nearest street intersection.



Some packages compares these distances.