Planning for transport and logistics

Jiří Vokřínek

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Logistics

plural noun: **logistics**

1. the detailed coordination of a complex operation involving many people, facilities, or supplies.
   "the logistics and costs of a vaccination campaign"
   synonyms: organization, planning, plans, management, arrangement, administration, orchestration, coordination, execution, handling, running More

   - MILITARY
     the organization of moving, housing, and supplying troops and equipment.
     noun: logistics
   - the commercial activity of transporting goods to customers.
     "Germany's largest beverage logistics organization"

Source: google search

Logistics – 218 B.C.

- 1 600 km
- 60 000 infantry, 10 000 cavalry, 37 war horses

Source: Wikimedia Commons

Logistics

- Production, storage, transportation
- **When** should the resource to be produced
  - Resource planning, production scheduling
- **Where** should the resource to be produced
  - Facility location optimization, layout planning

- Inventory vs. location vs. transportation

Logistics …

- Strategic (years)
  - Facilities size, location, transport modes (air, sail, rail, …)
- Tactical (months)
  - Inventory positioning, seasonal transport, customer rules, market optimization
- Operational (hours or days)
  - Routing, material replenishment, order expedition

… Transport

- Strategic (years)
  - Urban planning, transport systems construction optimization
- Tactical (months)
  - Trip modelling, travel forecasts, transport system optimization
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  - Routing problems, cost optimization

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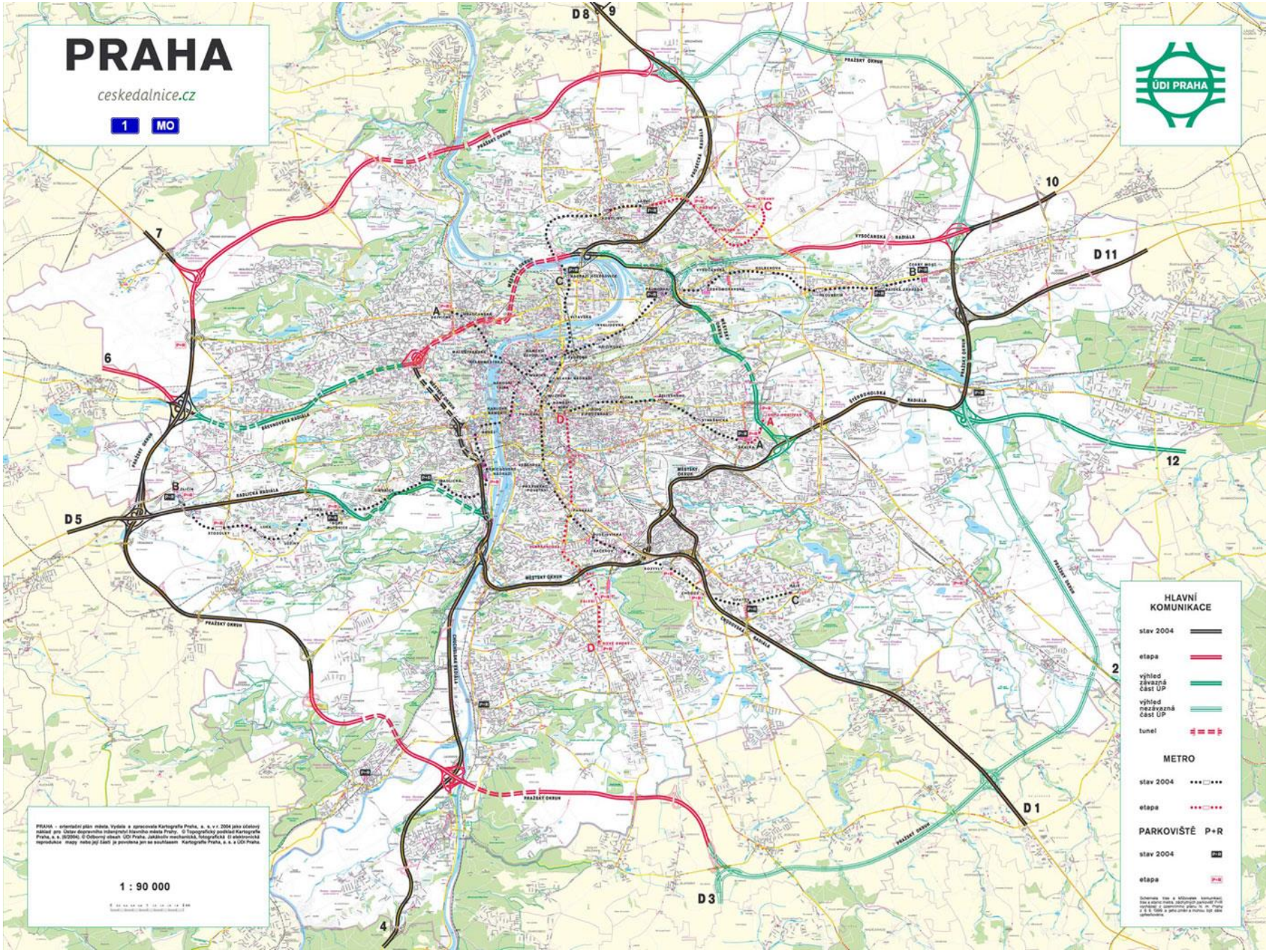
Transport System Planning

- Existing network models + existing traffic patterns
  - O/D (origin/destination) demand tables
  - Counters, statistics
  - Traffic flow patterns (predictions)
  - Urban planning/plans, population development
- Travel demand modelling was first developed in late 1950’ for highway planning

Source: www.ceskedalnice.cz



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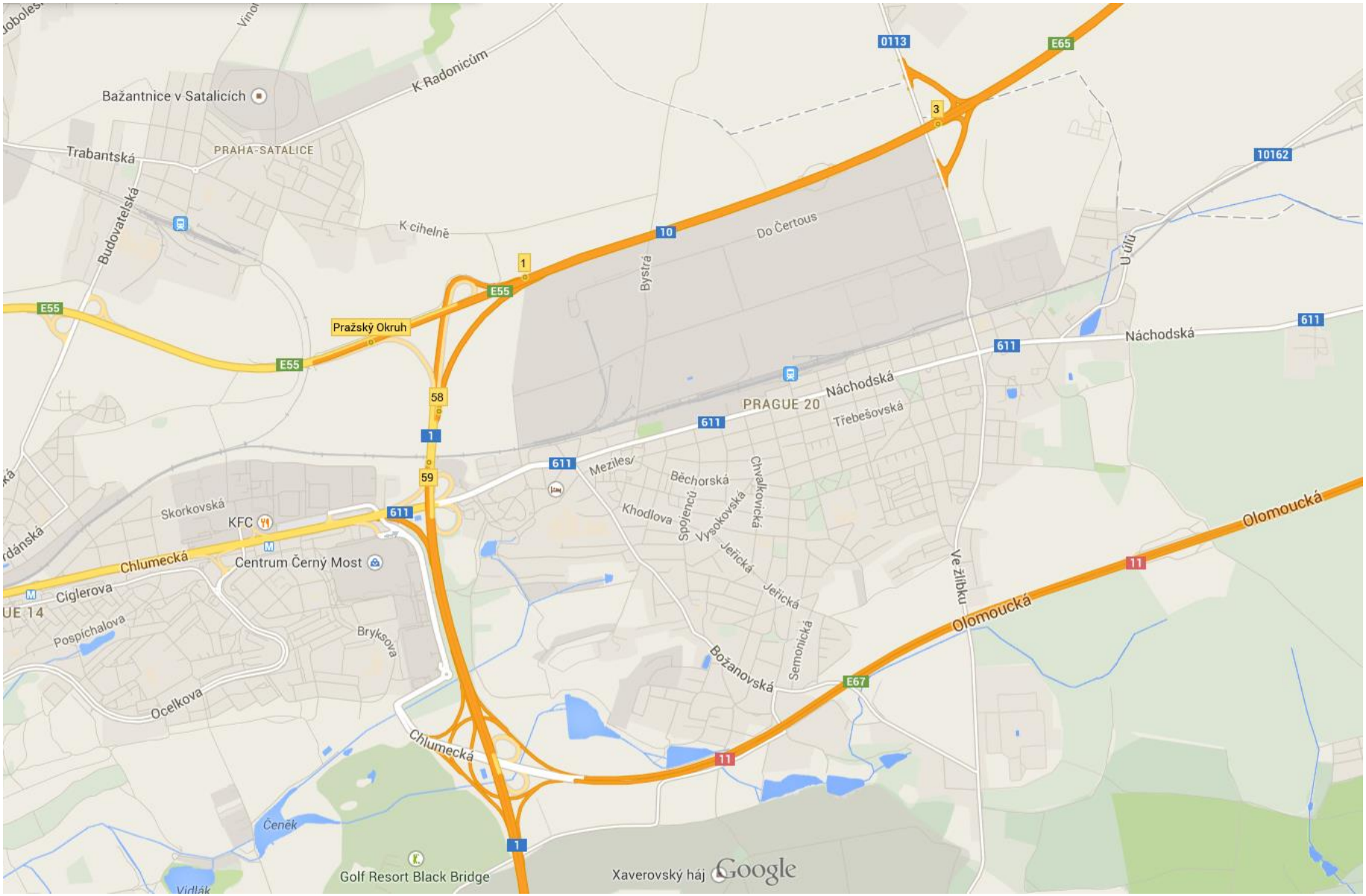


Source: www.google.com/maps

Transport System Planning

- Model building – finding parameters of the system
  - Number of trips attracted or generated to/by a certain area
  - Generate O/D travel demand table
  - Will then know how many travellers from O_x will go to D_y ; for all x,y pair.

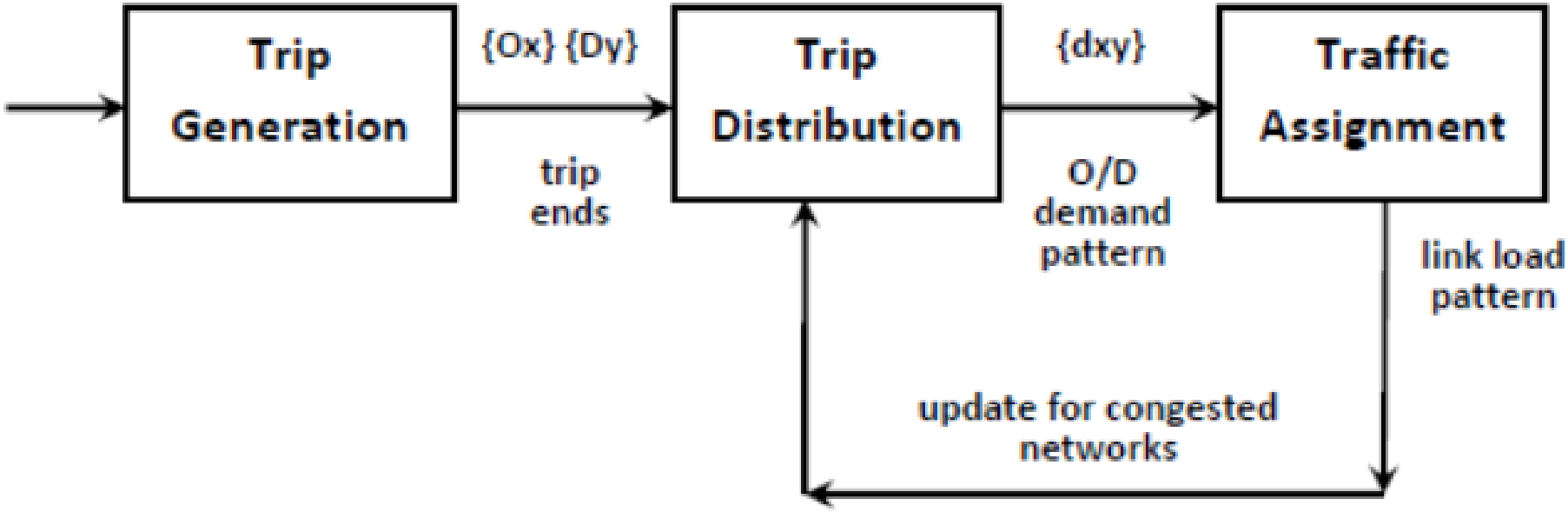
O_x = # of trips produced (generated) at zone x (production zone)

D_y = # of trips attracted to zone y (attraction zone)

Transport System Planning

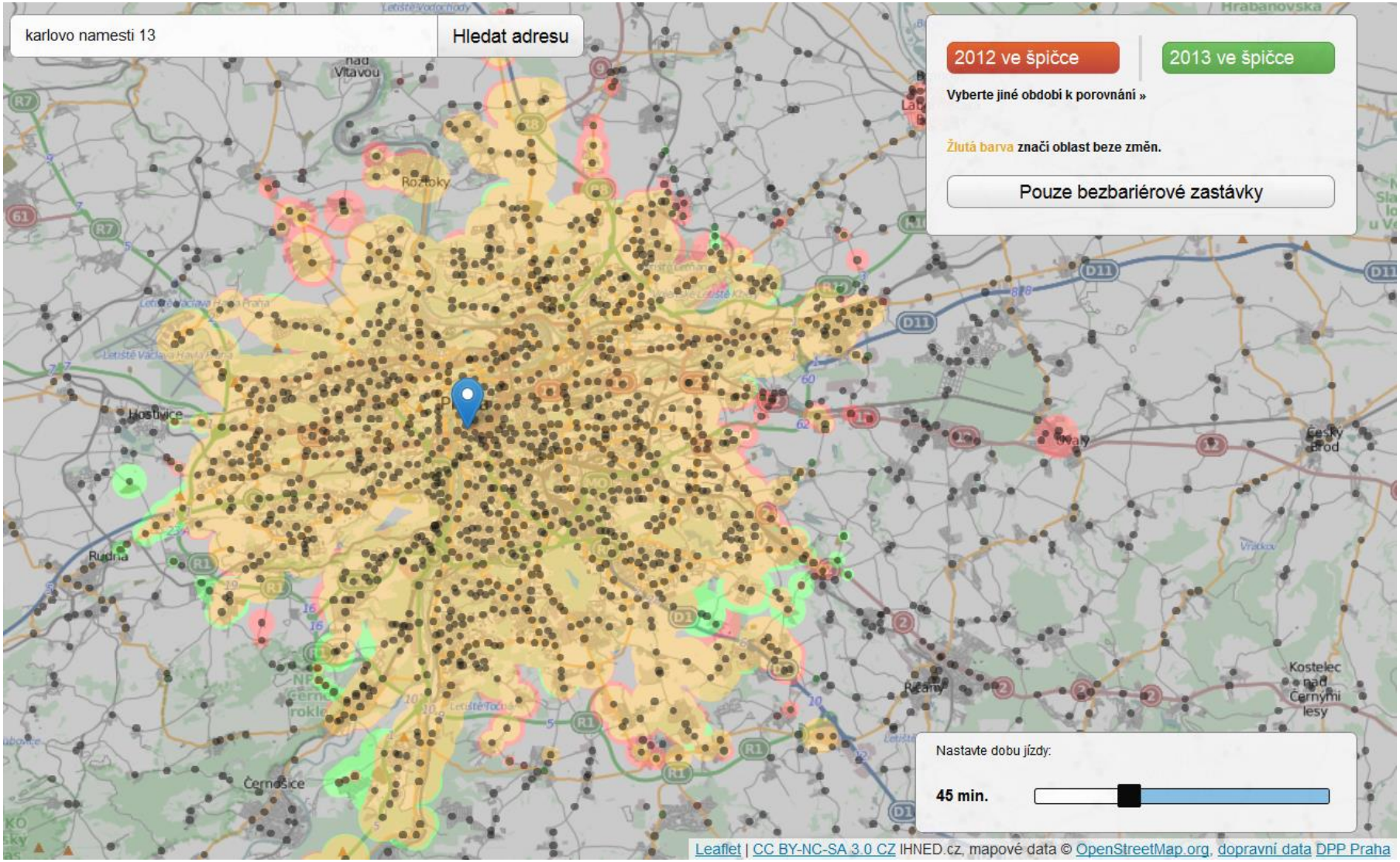
- Travel demand – $d_{xy} = kO_xD_y f(c_{xy})$
- Find how this travel demand is distributed among deferent routes and modes of transport
- Evaluate traffic network
- Forecast future O/D travel demand table
- Plan the network changes
- Evaluate network changes in simulation

Transport System Planning

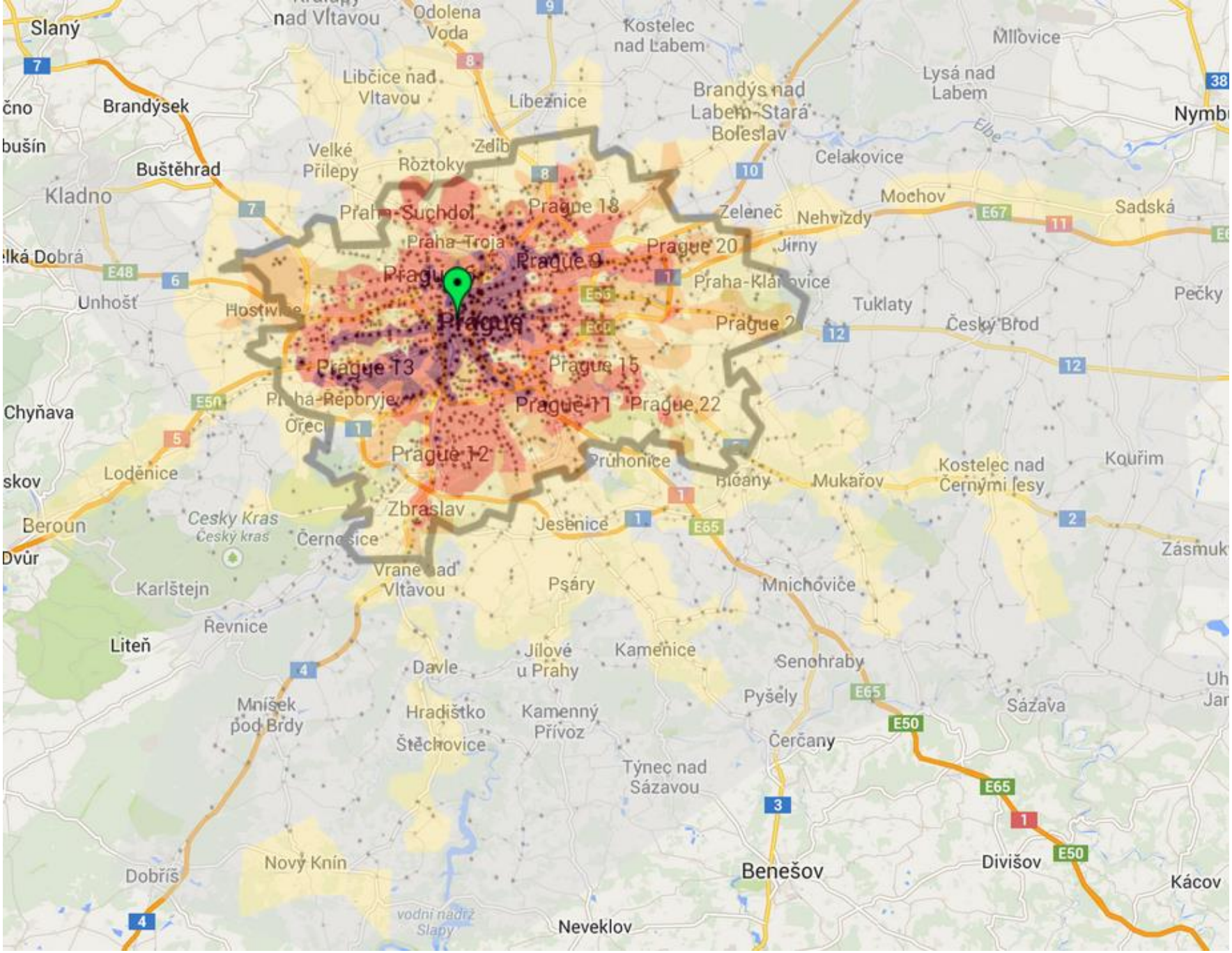


Source of the scheme: Dr. Anna Nagurney, FOMGT 341 Transportation and Logistics – L1

Transport System Planning



Source: ihned.cz/mhd



Source: transport.felk.cvut.cz/TransportAnalyser

Transport System Planning

- Main issues
  - How to collect the data?
  - How to represent the data?
  - Quality of future predictions?

- What will a community look like in the future?

  Birth/deaths rates, migration rates, age of population

- What are the travel patterns in the future?

  Employment, economic multipliers, urban development

Transport System Planning

- Main issues
  - How to collect the data?
  - How to represent the data?
  - Quality of future predictions?
- Main tools
  - Trip modelling
  - Network modelling
  - Path planning and simulation
  - Network optimization

Transport System Planning

- Trip modelling
  - Multiple regression
    - Combination of linear functions for each trip type
  - Cross-classification
    - Based on individual data (surveys), non-linearity
  - Modal split
    - Weighted priorities, time vs. cost -> trip planning
  - Typically based on “zoning system”
    - Affect the model, good at city-to-city level
- Trip planning for individuals based on model

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Transport System Optimization

- Given the
  - Transport system
  - Transport resources
  - Demand model
  - Trip model
  - A set of dynamic models variables
    - Easy (cheap) to change in transport system
    - Dynamic changes in demand/trip model (workdays, holidays, events, …)

-> find adjustments of the system to fit the needs

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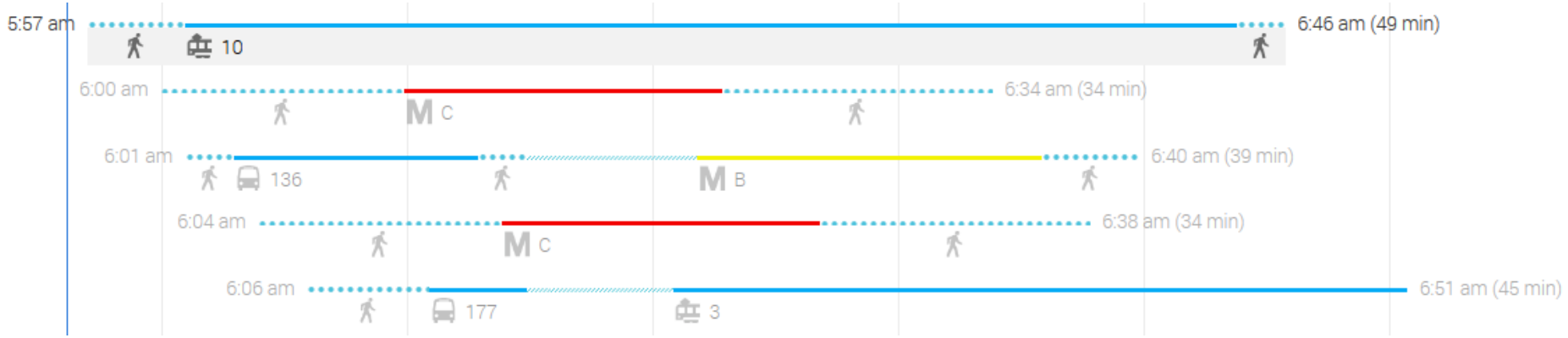
Cost of Transportation

- Time, money, comfort, ecology …

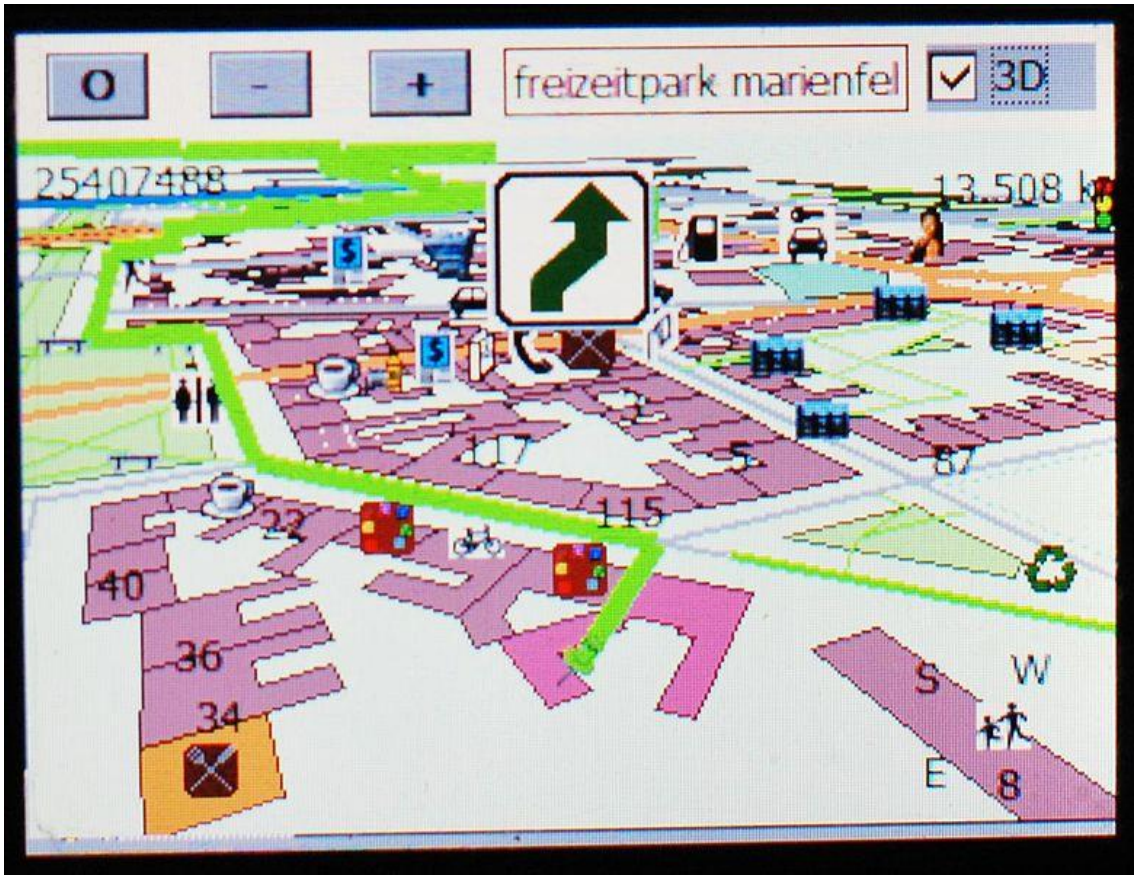
- Graph search on the traffic model for a trip



Source: www.google.com/maps

Cost of Transportation

- Personal (car) navigation – bike example



Source: Wikimedia Commons, Gosmore

Cost of Transportation in Logistics

- “Time is money …”

- High number of trips to be planned
- (shared) Transport resources to be optimized
- Large amount of constraints to be addressed
- Distribution networks and mail services

-> Hard planning problem

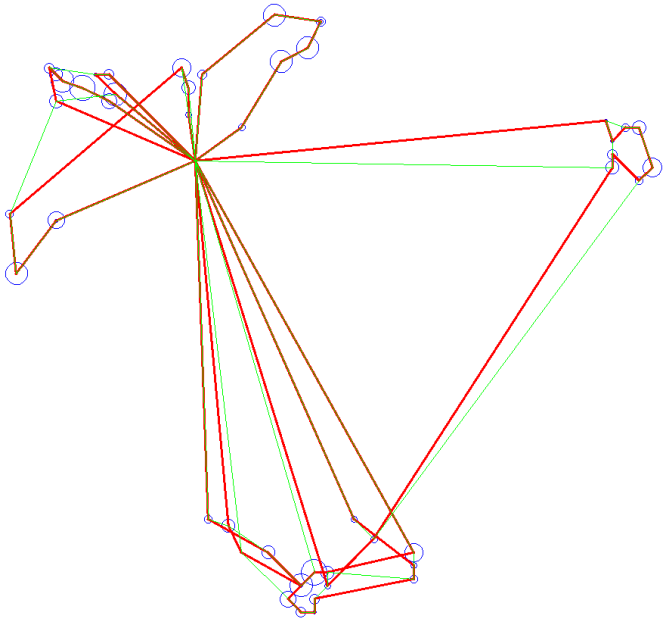
Cost of Transportation in Logistics

- Fixed
  - Terminals, hubs, administration
  - Transport equipment
  - Infrastructure (rail, pipelines, …)
- Variable
  - Fuel, labour, maintenance
  - Taxes, fees, handling, pickup/delivery
- Varies for different mode of transport

Vehicle Routing Problem

- *m* vehicles with defined capacity to deliver to *n* customers required volumes
- Using minimal *m* – bin-packing (BP) problem
- Using shortest trajectories – m-TSP problem

- Goal is to find a set of routes keeping given constraints and serving all the costumers



Vehicle Routing Problem

- Exact algorithms
  - Integer programming
  - Branch and bound

  - Optimal, but may be slow on large problems
  - Difficult to include additional constraints

Vehicle Routing Problem

- Heuristic
  - Construction h. – building feasible routes
  - Improvement h. – improve feasible routes
  - Consistency and feasibility given by a set of constraints

  - Not optimal, but efficient
  - Usually modifications of TSP heuristics
  - In practical cases *m* is given by strategic planning

Vehicle Routing Problem

- **Construction heuristics**
  - Cluster methods
    - Cluster first, route second (BP -> m-TSP)
    - Route first, cluster second (TSP -> satisfy BP)
- Routing
  - Nearest neighbour
  - Cheapest insertion
  - Sweep algorithm
  - Savings method

Vehicle Routing Problem

- Nearest neighbour
  - Start with the closest customer
  - Add unserved customer nearest to the end of the route
  - Start a new route when vehicle is full
  - Re-optimize each route at the end

  - Easy to build
  - Good TSP heuristic
  - Overlapping routes

Vehicle Routing Problem

- Cheapest insertion
  - Start with empty routes
  - Add an unserved customer to the route with minimal route cost increase
  - Stop using a new route when vehicle is full
  - Re-optimize each route at the end

  - Incremental method
  - Good TSP heuristic
  - Overlapping routes

Vehicle Routing Problem

- Sweep algorithm
  - Draw a ray starting from depot
  - Sweep clockwise and add customers to the route
  - Start a new route when vehicle is full
  - Re-optimize each route at the end

  - Geometrically easy understanding
  - Not overlapping routes
  - Such clustering is good for TSP

Vehicle Routing Problem

- Savings method
  - Build a route for each customer separately
  - Calculate savings for joining two routes
  - Join the routes for the best savings
  - Stop using a route when vehicle is full
  - Stop when no routes can be joined

  - Iterative construction keeping feasibility of the solution
  - Good results, more complex than previous ones

Vehicle Routing Problem

- **Improvement heuristics**
  - Given (feasible) set of routes find an improved solution
  - Exchange within a route
    - *k*-opt arc exchange, customer position switch
  - Exchange between routes
    - Move customer, switch two (three) customers
  - Local search
    - Simulated annealing, tabu search, genetic algorithms

Vehicle Routing Problem

- **Solution constraints**
  - Affect feasibility, consistency and cost of the solution
  - Enrich problem variants
    - Time windows, heterogeneous vehicles, multiple-depots, drivers working hours, demands compatibility, priorities, pick-up and deliveries, on demand delivery, backhauls, …
- A lot of problem variants – very complex and (often) unique constraints in the real world

Future Transport Planning?

Development is fast

Need a good planning

Source: www.amazon.com, www.transportjournal.com/uploads/pics/Goodman-Amazon-Poland.jpg