

**Schietzelt, T. H. and Densham, P.  
J. 2003.**

## **Location-allocation in GIS**

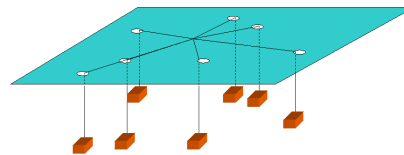
### GIS Applications

Use of analytical GIS tools to:

- Describe
- Explain
- Predict
- Support decision-making
  - Prescribe (i.e., prescriptive or normative use of GIS)

# Location-Allocation

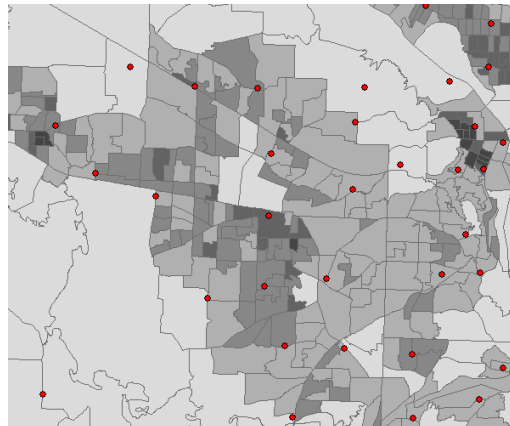
- 1) Where to **locate** and 2) how to **allocate** demand for service to the central facility.
- Point of minimum aggregate travel (MAT)
- Varignon



1-median problem

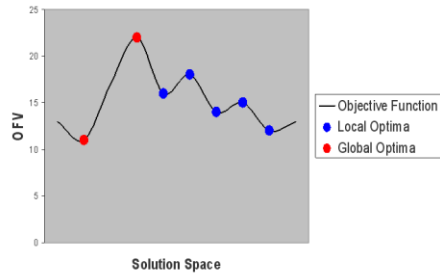
## p-median Problem

- To find optimum locations of  $p$  facilities such that the sum of the (weighted) distance between each demand location and the nearest facility is minimized.



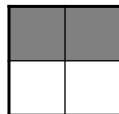
# Optimization

- Finding the best solutions to a problem
- Operations research
- Considerations:
  - Single and multi-objective problems
  - Static or dynamic
  - Constraints (capacitated)
  - Objective function



## Combinatorial Optimization

- Problem: find the pattern that produces the longest perimeter in a 2 by 2 gridded landscape with 2 foreground cells (black) and 2 background cells (white).
- How many different patterns (solutions) are there?
- ${}_4C_2 = (4 \cdot 3) / (1 \cdot 2) = 6$



# Solving p-medium

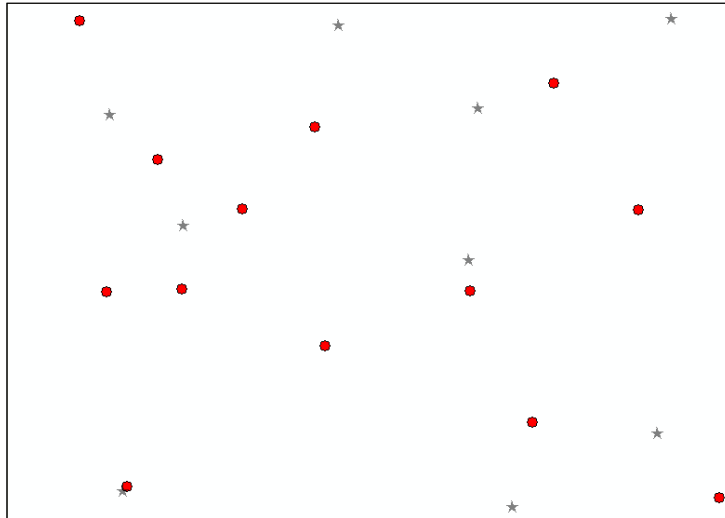
- Combinatorial optimization
  - Seeking the best combination of demand locations allocated to p facilities.
- Complete enumeration
- “Hard” problems (NP-Hard)

$${}_{100}C_{50} = \frac{100!}{50!(100-50)!} > 10^{29} \quad (\text{i.e. if a computer can generate 100M solutions/sec, then it takes 100B centuries to finish.})$$

## Solution Methods

- Exact (based on math equations)
  - Integer linear programming
  - Branch and bound
  - Lagrange relaxation
- Basic heuristics (iterative trial and error)
  - ADD, Drop
  - Global Regional Interchange Algorithm (GRIA)
  - Swapping (n-opt)
  - Greedy (uphill-climbing) method
- Advance heuristics (iterative trial and error)
  - e.g., Simulated annealing

# Example



## GRIA (Global Regional Interchange Algorithm)

- GRIA begins with a 'starting solution', or 'seed', of  $m$  candidates. The algorithm then goes through a global phase and a regional phase of candidate substitutions.
- Global phase
  - Select  $p$  sites. A site in  $p$  is selected that makes the least increase in the total weighted distance once it is removed from the solution. It is replaced with the candidate that decreases the total weighted distance the most. These substitutions are done until there is no further reduction in the total weighted distance.
- Regional phase
  - Involves looking at the candidates allocated to each site. If a site can be replaced by one of these candidates to reduce the total weighted distance, the substitution is made. These substitutions are done until there is no further reduction in the total weighted distance.

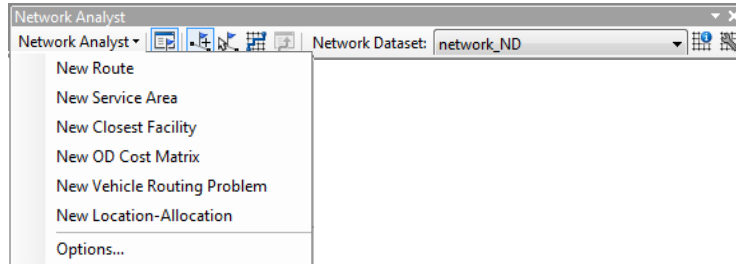
## Measuring Distance (Accessibility)

- Euclidian distance
- Cost-distance (accessibility)
- Cost function
  - Determined by distance
  - Linear or non-linear
  - Deterministic constant or stochastic random variable

## Location-Allocation Example (Emergency Medical Services)

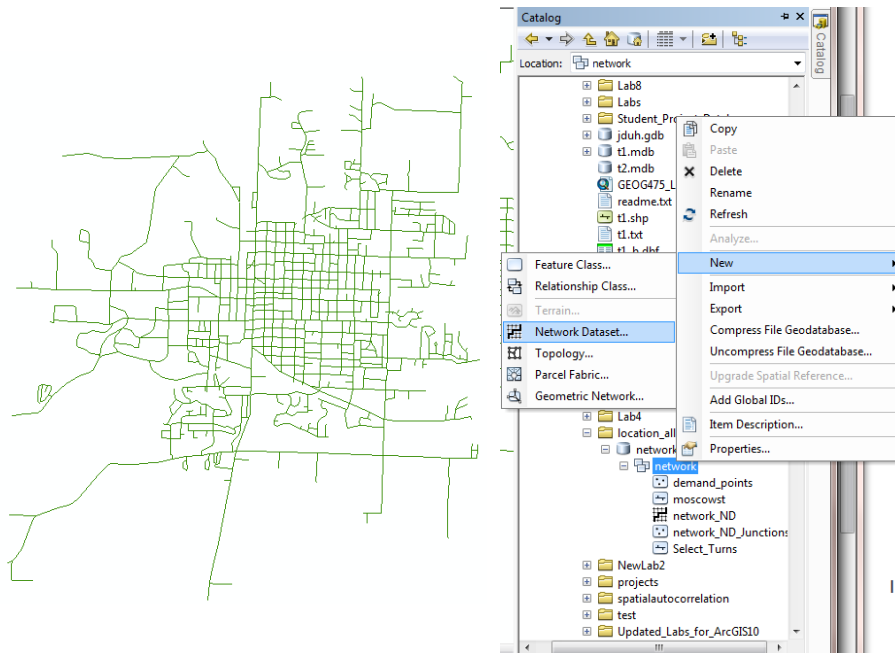
- Demands
  - Single / multi-supply
  - Dynamic
- Supplies
  - Capacitated / non-capacitated
- Cost-function
  - Network distance
  - Congestion/delay

# Location-Allocation in ArcGIS 10

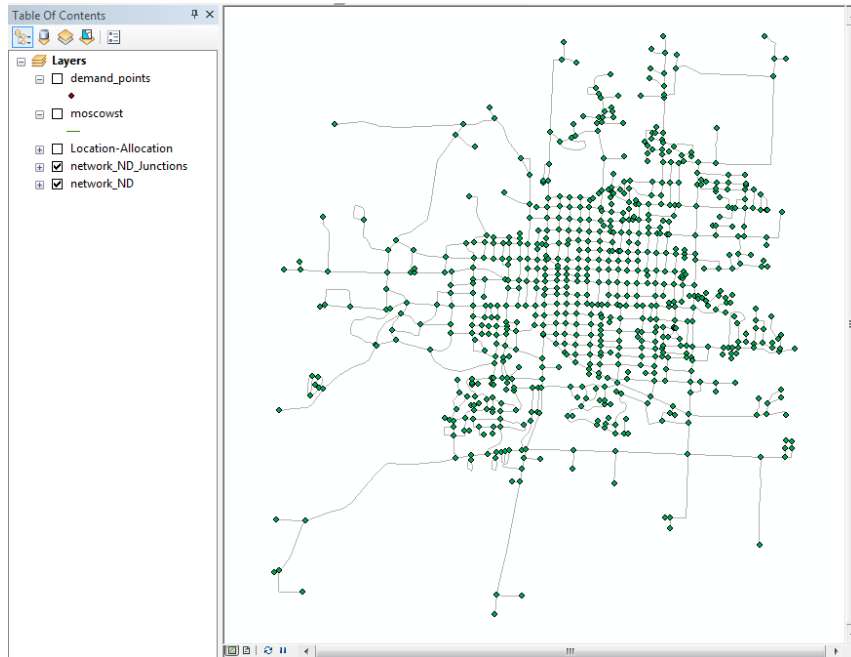


- You need:
  - Network Analyst extension
  - A network dataset
  - A demand-points feature class
  - A candidate facilities feature class

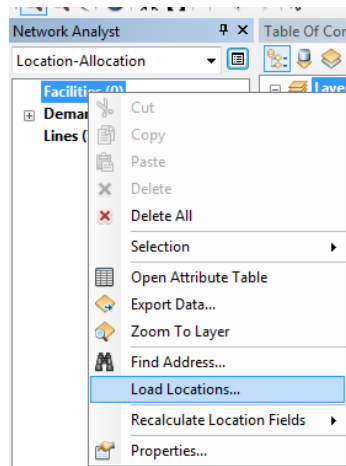
Use Catalog network wizard to create a network from a street layer



## A network with edges and junctions...



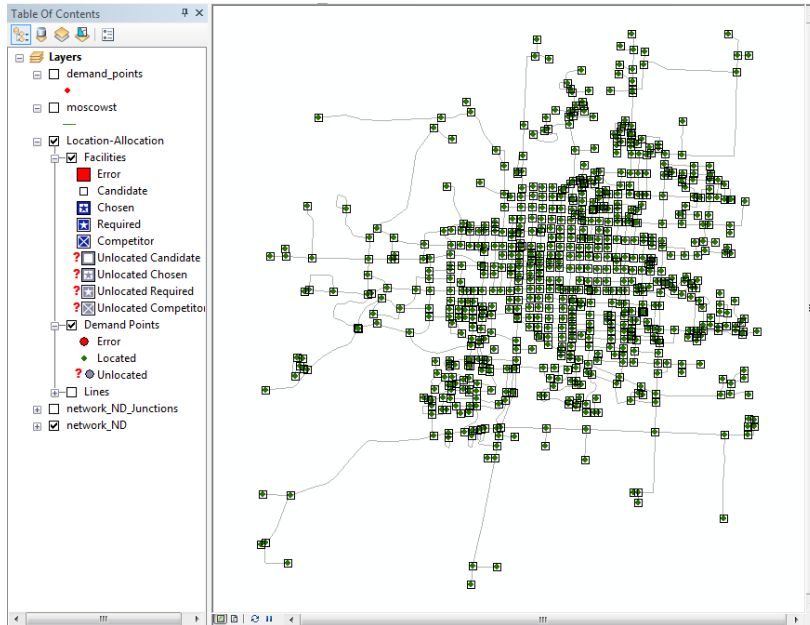
Prepare demand points and candidate locations, load them to the Network Analyst ...



- I used the network junctions to create the demand points and candidate facility locations



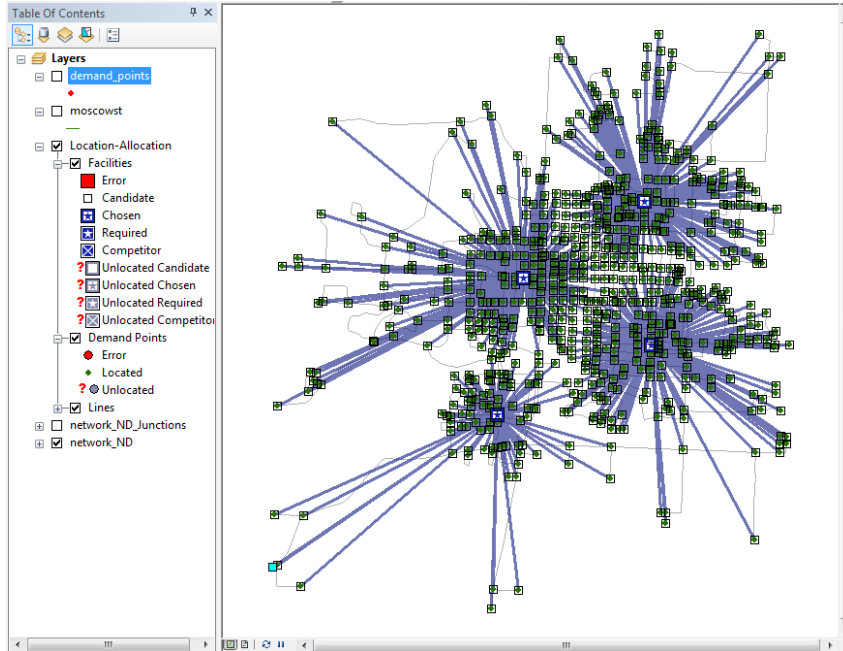
Ready to solve the location-allocation problems...



## Location-Allocation Problem Types

Type	Description	Applications
Minimize Impedance (P-Median)	Facilities are located such that the sum of all weighted costs between demand points and solution facilities is minimized.	Locate warehouses
Maximize Coverage	Facilities are located such that as many demand points as possible are allocated to solution facilities within the <b>impedance cutoff</b> .	Locate fire stations
Minimize Facilities	Facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cutoff; additionally, the number of facilities required to cover demand points is minimized.	Locate fire stations without budget limit
Maximize Attendance	Facilities are chosen such that as much demand weight as possible is allocated to facilities.	Locate stores without competitors
Maximize Market Share	A specific number of facilities are chosen such that the allocated demand is maximized in the presence of competitors.	Locate store with competitors
Target Market Share	Target Market Share chooses the minimum number of facilities necessary to capture a specific percentage of the total market share in the presence of competitors.	Locate store with competitors but without budget limit

## Solution: Minimizing impedance with 4 facilities



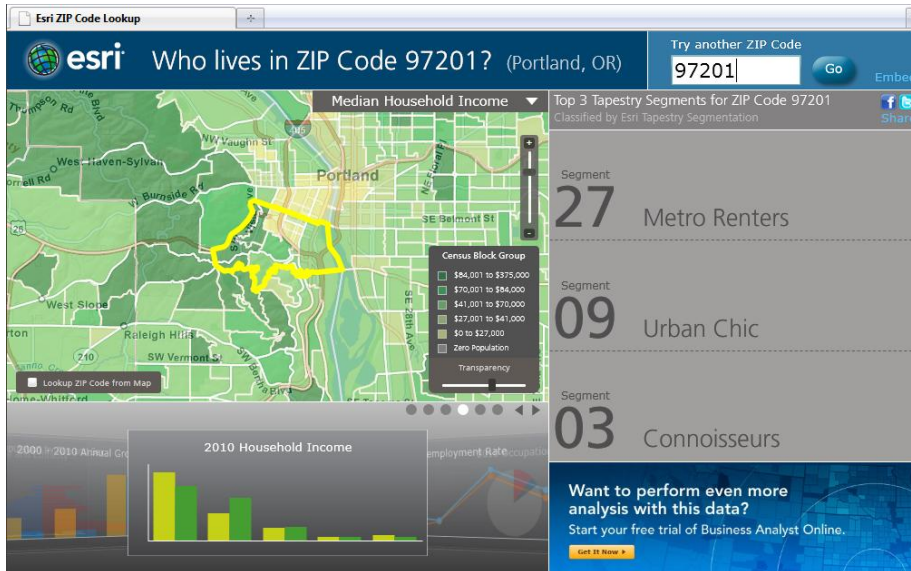
## Location-Allocation in ArcInfo

- You need a network coverage (e.g., **roads**) containing a route (e.g., **routes**), a point coverage of demands (e.g., **demandpts**), and a list of candidate locations (e.g., **roads.cen**)
- The AAT of the network coverage should have an attribute field indicating the cost of travel (or impedance) (e.g., length)
- The PAT of point coverage should have an attribute field indicating the number of demands (e.g., popu)
- The following commands find 3 nodes on the network as supply centers
 

```
Arc: w C:\Users\Myworkspace
Arc: arcplot
Arcplot: disp 9999 /* set the map output to the standard output window - 9999
Arcplot: mape roads /* use the extend of roads to set the mapextent
Arcplot: arcs roads /* plot the arcs of the roads coverage
Arcplot: nodes roads /* plot the nodes of the roads coverage
Arcplot: pointmarkers demandpts 4 /* 4 is the symbol of a blue cross
Arcplot: netcover roads routes /* use the routes feature in the roads coverage to define the network
Arcplot: impedance length /* specify the impedance of the network
Arcplot: centers roads.cen /* use the road nodes listed in the roads.cen table as centers
Arcplot: locatecandidates CENTERS /* use the centers as location allocation candidates
Arcplot: locatecandidates demandpts POINT popu /* use the demandpts as demands
Arcplot: locateallocate outalloc outcenters outglob 3
Arcplot: show locateallocate
```
- Use ARCROUTE command to create a route.

# ESRI BAO (Business Analyst Online)

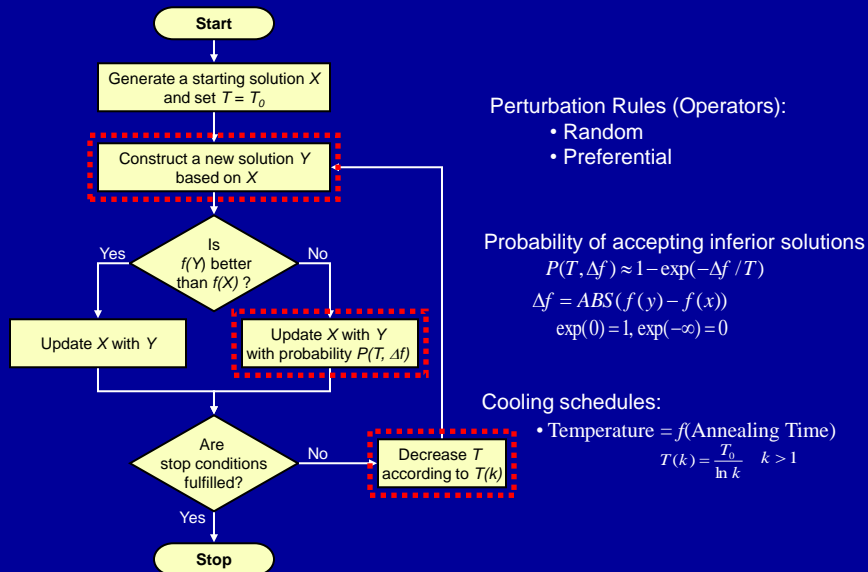
- <http://www.esri.com/software/bao/index.html>



## Meta-Heuristic Methods

- Won't guarantee finding global optima
- Different initial solutions result in different final solutions
- Two phases search
  - Explore
  - Exploit

# Simulated annealing



## p-median & Geographic Districting

- p-median problem is a special case of Geographic Districting problem.