Chapter 17. PATH ANALYSIS AND NETWORK APPLICATIONS

Path Analysis

- Using a cost raster that defines the cost of moving through each cell, path analysis finds the least cost path between cells.
- A path analysis requires a source raster, a cost raster, cost distance measures, and an algorithm for deriving the least accumulative cost path.
- A source raster defines the source cell.
- A cost raster defines the cost or impedance to move through each cell. The cost distance measure is based on the node-link cell representation.
- The process for finding the least accumulative cost path is an iterative process based on Dijkstra's algorithm.

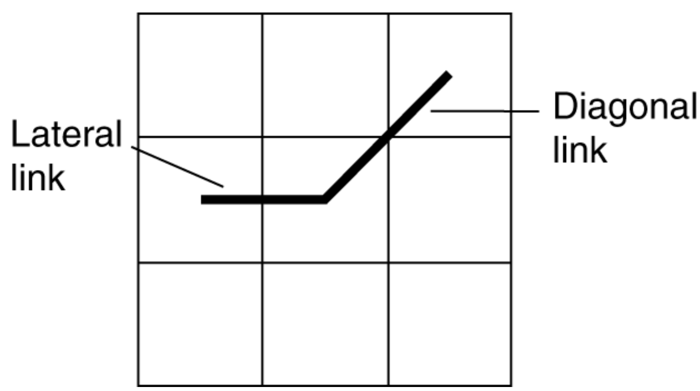


Figure 17.1
Cost distance measures follow the node-link representation: a lateral link connects two direct neighbors, and a diagonal link connects two diagonal neighbors.

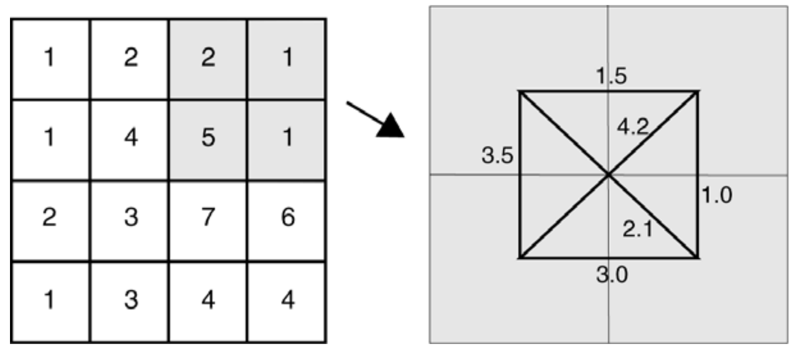


Figure 17.2
The cost distance of a lateral link is the average of the costs in the linked cells, for example, (1 + 2) / 2 = 1.5. The cost distance of a diagonal link is the average cost times 1.4142, for example, 1.4142 x [(1 + 5) / 2] = 4.2.

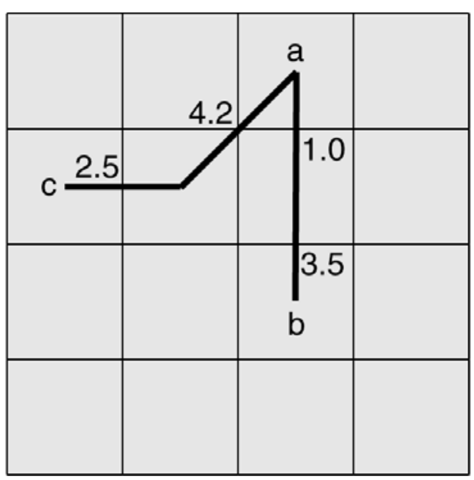


Figure 17.3
The cumulative cost from cell *a* to cell *b* is the sum of 1.0 and 3.5, the costs of two lateral links. The cumulative cost from cell *a* to cell *c* is the sum of 4.2 and 2.5, the costs of a diagonal link and a lateral link.

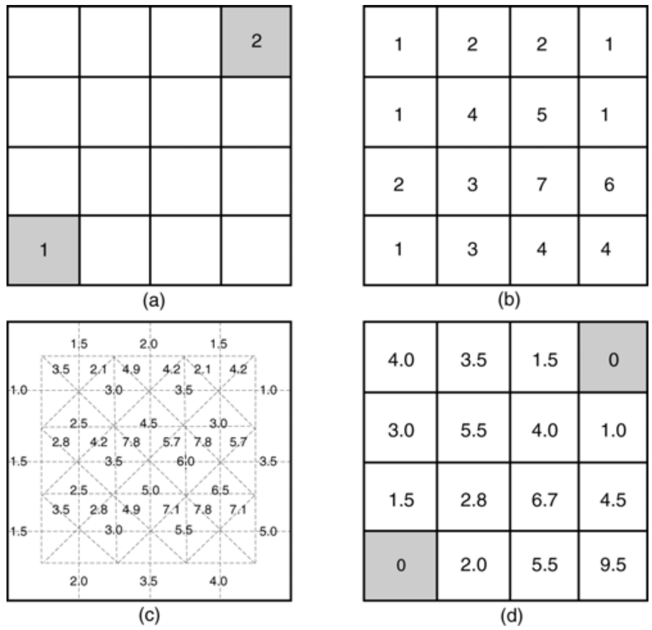


Figure 17.4
The cost distance for each link (c) and the least accumulative cost distance from each cell (d) are derived using the source cells (a) and the cost raster (b). See Box 17.2 for the derivation.

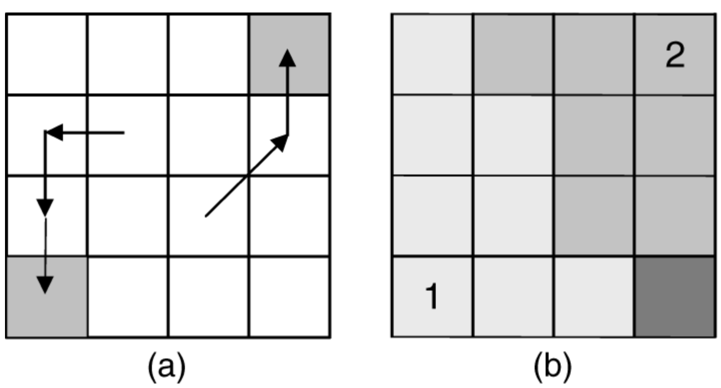


Figure 17.5
The least cost path (a) and the allocation raster (b) are derived using the same input data as in Figure 17.4.

Network

- A network is a system of linear features that has the appropriate attributes for the flow of objects.
- A network is typically topology-based: lines (arcs) meet at intersections (junctions), lines cannot have gaps, and lines have directions.
- Attribute data of a road network include link impedance, turns, one-way streets, and overpasses/underpasses.

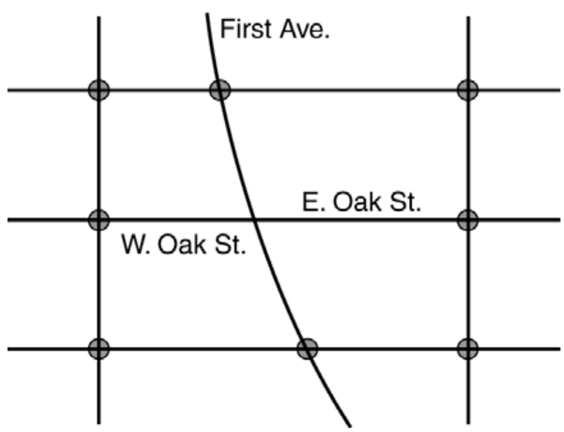
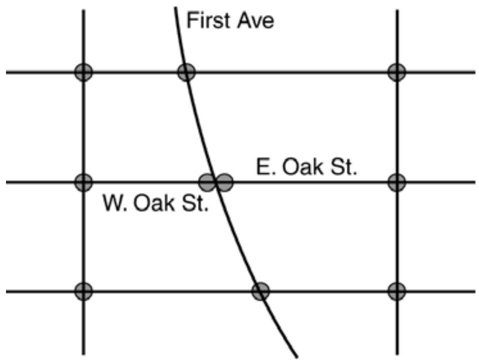


Figure 17.6
First Ave. crosses Oak St. with an overpass. A nonplanar representation with no nodes is used at the intersection of Oak St. and First Ave.



Street name	F-elev	T-elev
First Ave	0	1
First Ave	1	0
W. Oak St.	0	0
E. Oak St.	0	0

Figure 17.7
First Ave. crosses Oak St. with an overpass. A planar representation with two nodes is used at the intersection: one for First Ave., and the other for Oak St. First Ave has 1 for the T-elev and F-elev values, indicating that the overpass is on First Ave.

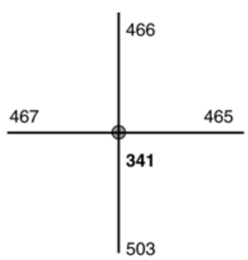


Figure 17.8
Possible turns at node 341.

Node#	Arc1#	Arc2#	Angle	Minutes
341	503	467	90	0.500
341	503	466	0	0.250
341	503	465	–90	0.250
341	467	503	–90	0.250
341	467	466	90	0.500
341	467	465	0	0.250
341	466	503	0	0.250
341	466	467	–90	0.250
341	466	465	90	0.500
341	465	503	90	0.500
341	465	467	0	0.250
341	465	466	–90	0.250

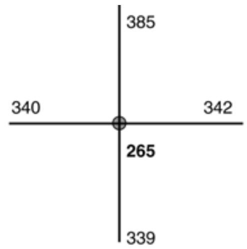


Figure 17.9
Node 265 has stop signs for the east–west traffic. Turn impedance applies only to turns in the shaded rows.

Node#	Arc1#	Arc2#	Angle	Minutes
265	339	342	–87.412	0.000
265	339	340	92.065	0.000
265	339	385	7.899	0.000
265	342	339	87.412	0.500
265	342	340	–0.523	0.250
265	342	385	–84.689	0.250
265	340	339	–92.065	0.250
265	340	342	0.523	0.250
265	340	385	95.834	0.500
265	385	339	–7.899	0.000
265	385	342	84.689	0.000
265	385	340	–95.834	0.000

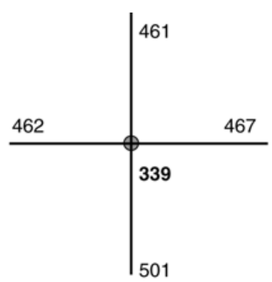


Figure 17.10
Node 339 is an intersection between a southbound one-way street and an east–west two-way street. Notice –1 (no turn) in the shaded rows.

Node#	Arc1#	Arc2#	Angle	Minutes
339	467	501	90.190	0.500
339	467	462	1.152	0.250
339	467	461	–92.197	–1.000
339	462	501	–90.962	0.250
339	462	467	–1.152	0.250
339	462	461	86.651	–1.000
339	461	501	2.386	0.250
339	461	467	92.197	0.500
339	461	462	–86.651	0.250

Shortest Path Analysis

Shortest path analysis finds the path with the minimum cumulative impedance between nodes on a network. The path may connect just two nodes—an origin and a destination—or have specific stops between the nodes.

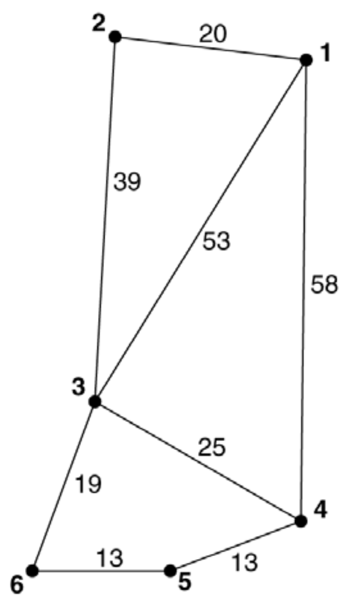


Figure 17.11
Link impedance values between cities on a road network.

	(1)	(2)	(3)	(4)	(5)	(6)
(1)	∞	20	53	58	∞	∞
(2)	20	∞	39	∞	∞	∞
(3)	53	39	∞	25	∞	19
(4)	58	∞	25	∞	13	∞
(5)	∞	∞	∞	13	∞	13
(6)	∞	∞	19	∞	13	∞

TABLE 17.1 The Impedance Matrix among Six Nodes in Figure 17.11

From-node	To-node	Shortest Path	Minimum Cumulative impedance
1	2	p_{12}	20
1	3	p_{13}	53
1	4	p_{14}	58
1	5	$p_{14} + p_{45}$	71
1	6	$p_{13} + p_{36}$	72

TABLE 17.2 Shortest Paths from Node 1 to All Other Nodes in Figure 17.11

Closest Facility

Closest facility finds the closest facility, such as a hospital, fire station, or ATM, to any location on a network.

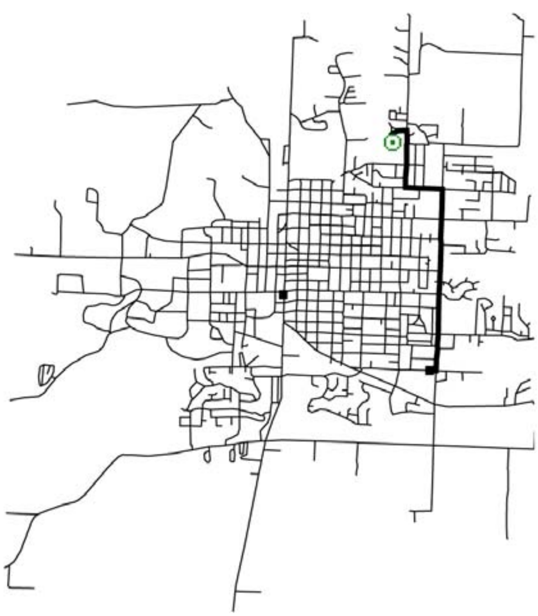


Figure 17.12 Shortest path from a street address to its closest fire station, shown by the square symbol.

Allocation

Allocation measures the efficiency of public facilities, such as fire stations, or school resources, in terms of their service areas.

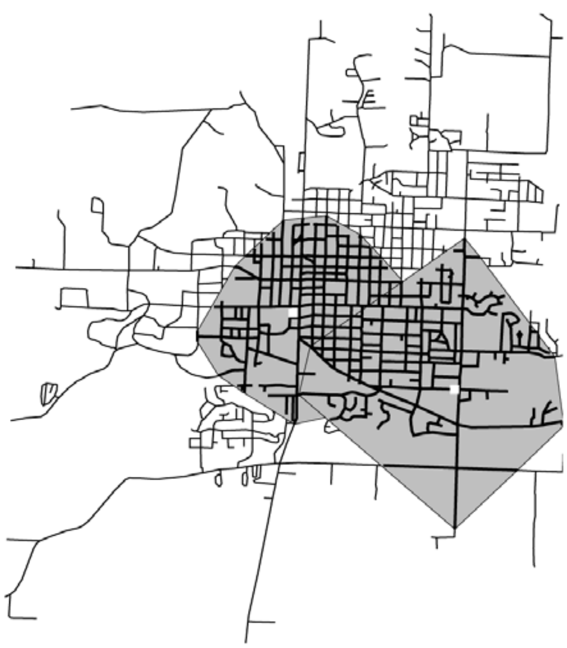


Figure 17.13 Service areas of two fire stations within a 2-minute response time.

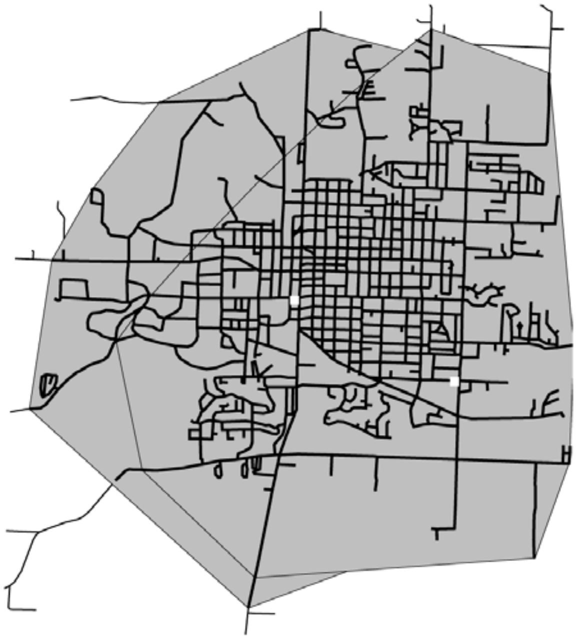


Figure 17.14 Service areas of two fire stations within a 5-minute response time.

Location-Allocation

Location–allocation solves problems of matching the supply and demand by using sets of objectives and constraints.

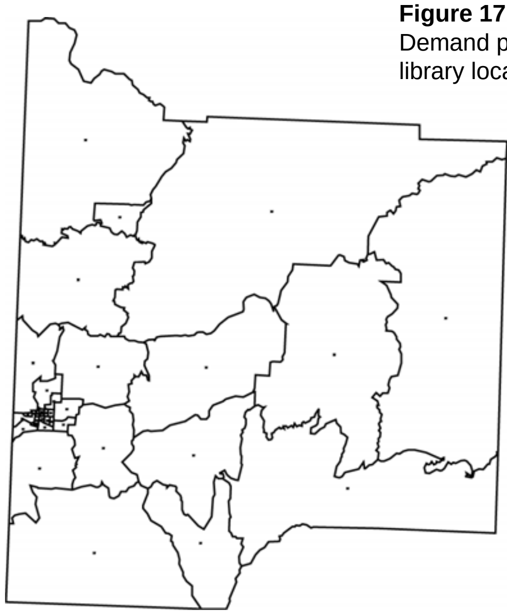


Figure 17.15
Demand points for a public library location problem.

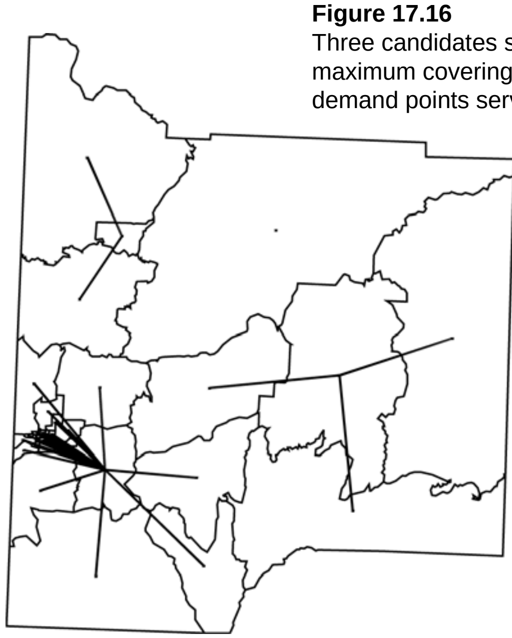


Figure 17.16
Three candidates selected by the maximum covering model and the demand points served by the candidates.

Figure 17.17
Three candidates selected by the minimum distance model and the demand points served by the candidates.

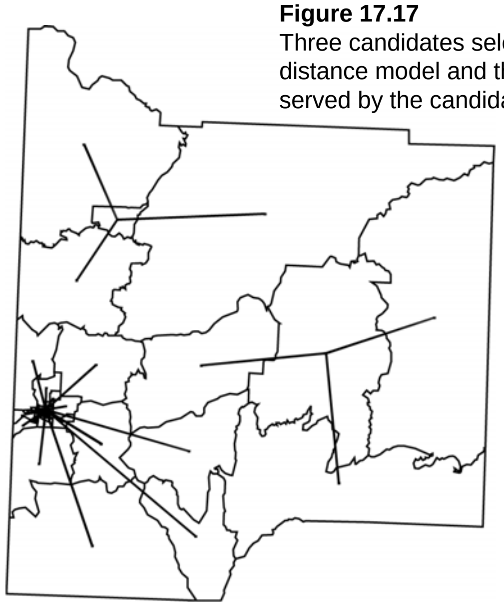


Figure 17.18
One fixed and two selected candidates using the minimum distance model with the maximum distance constraint of 10 miles. The fixed candidate is the one to the west.