

Introduction to Transportation Systems

PART III:
TRAVELER
TRANSPORTATION

Chapter 25:

The Urban Transportation Planning Process and Real-Time Network Control

Networks

- ◆ We are interested in *network behavior* -- how the network as a whole behaves -- which involves going from choices that individual people make about transportation to understanding how the network in its entirety operates.
- ◆ What are the flows on the network?
- ◆ What are the levels-of-service being provided?
- ◆ How much capacity is needed at various links and nodes?
- ◆ What might be done to enhance the network?
- ◆ How can we control the network in real-time?
- ◆ We need to *aggregate* predicted individual choices to overall network flows and performance.

The Urban Transportation Planning Process

- ◆ We begin the process by building a network.
- ◆ In performing this kind of analysis, we take a set of geographical areas, and aggregate them into what are called “zones”.
- ◆ For each zone, we define a node or centroid, often at the population center or major activity center of the zone.
- ◆ A network is constructed by connecting the nodes with links.

Constructing a Network from Zones

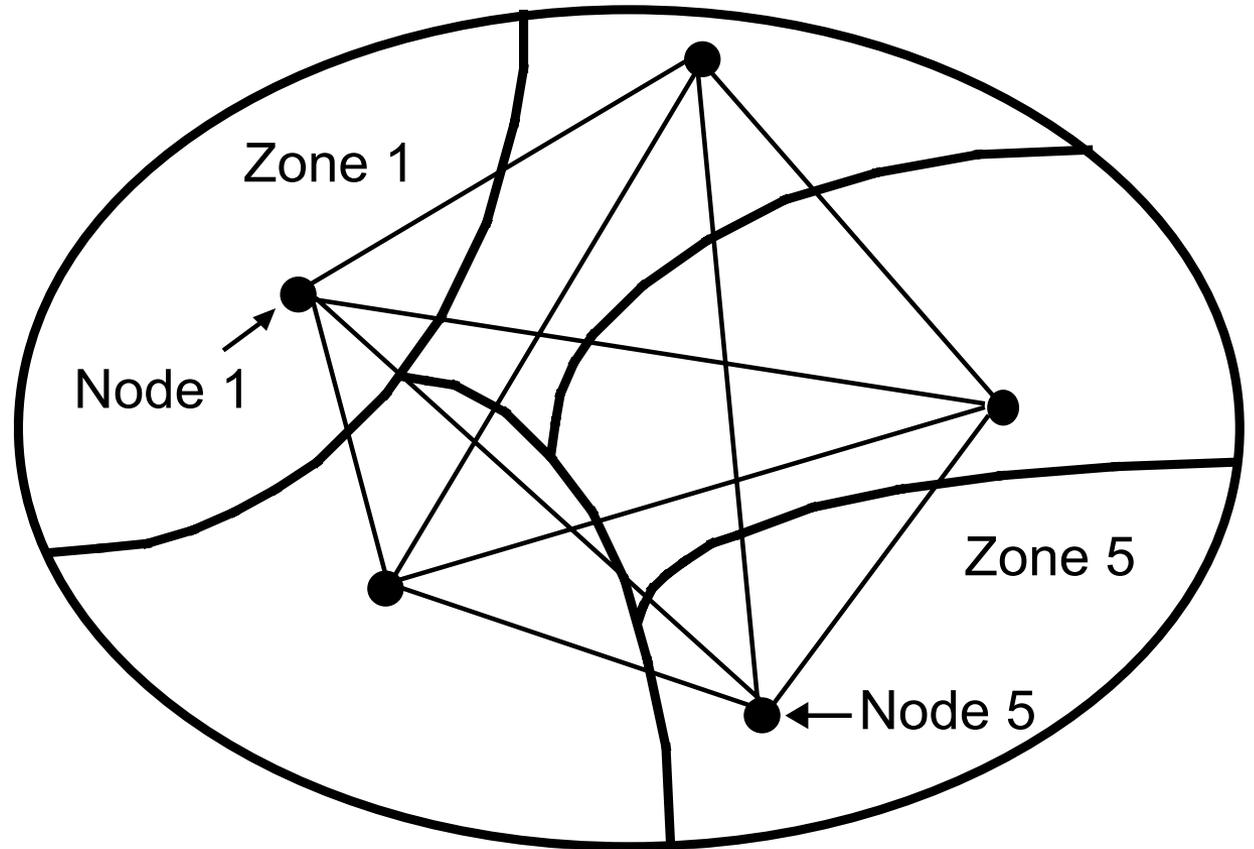


Figure 25.1

- ◆ On this network, we overlay the transportation network which is usually multimodal including, say, highway (both auto and bus) and rail transit.

Nodes as Zone Centroids and “Dummies”

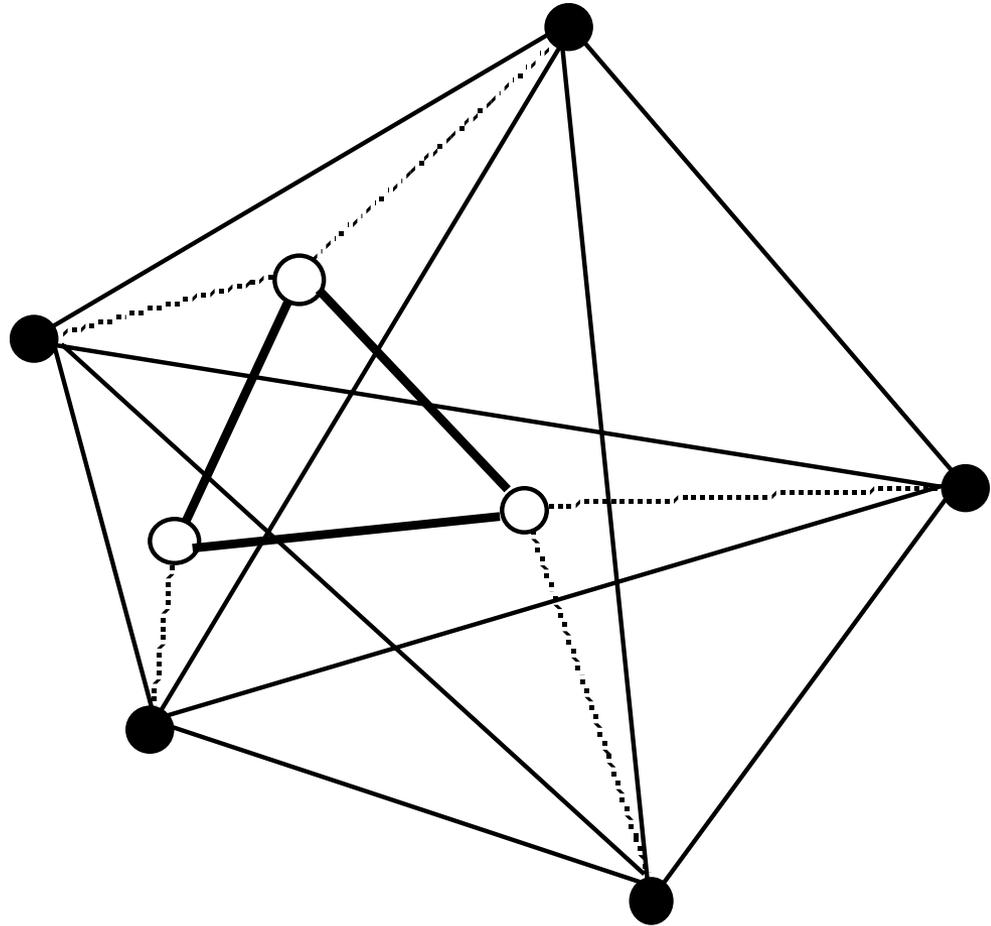


Figure 25.2

Choosing the Number and Size of Zones

- ◆ There is a fundamental modeling trade-off here. We can choose a relatively small number of large-area *heterogeneous* zones, which makes network analysis easy because with a small number of zones, the network is simple.
- ◆ Alternatively, we can choose a large number of smaller *homogenous* zones with the characteristics of individuals within those zones more alike; however, we then have a large number of zones, and a network that may be too complex to effectively analyze.

The Urban Transportation Planning Process

- ◆ Trip Generation
- ◆ Trip Distribution
- ◆ Mode Split
- ◆ Assignment

Origin-Destination Matrix

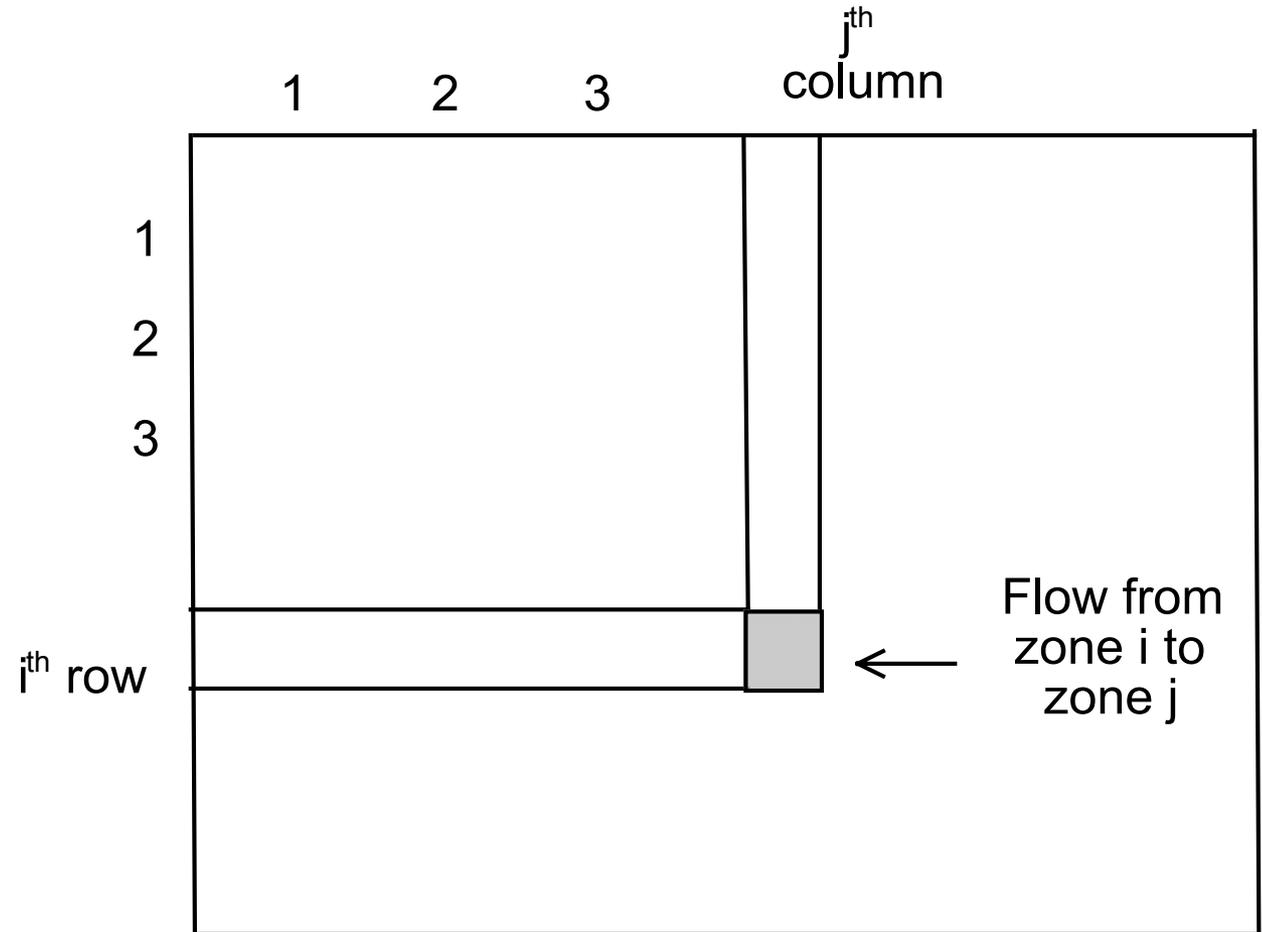
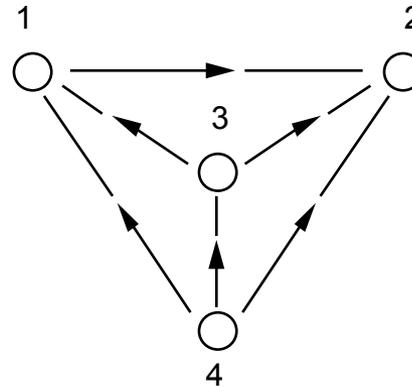


Figure 25.3

Assignment / User-Equilibrium

- ◆ User-equilibrium is based upon the idea that each user in the system is trying to optimize their own trip through the system.
- ◆ Each traveler, in true micro-economic fashion, is trying to optimize his trip without concern for other travelers.
- ◆ User-equilibrium is said to be achieved when all the paths that are *used* between any origin-destination pair all have the same travel time. Unused paths will have a larger travel time.

Flows between Node Pairs

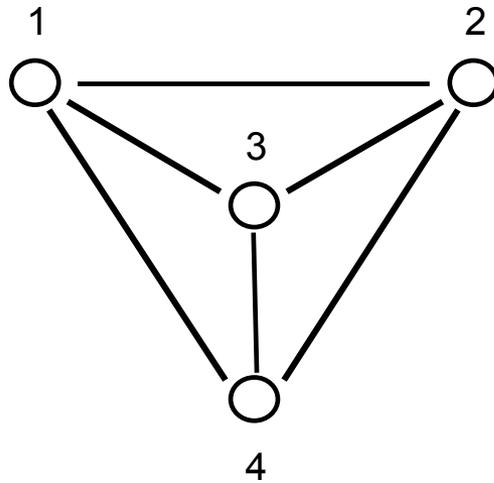


- ◆ Consider, for example, trips between Node 1 and Node 2. One can go from Node 1 to Node 2 directly from Node 1; one can also go from Node 1 to Node 2 via Node 3. Another possibility is Node 1 to Node 4 to Node 3 to Node 2. And there are others.
- ◆ User-equilibrium occurs when all the *used* paths between 1 and 2 (if that was the only flow) have the same travel time and all unused paths have a longer travel time. Simply put, no one gains by switching.
- ◆ Now, usually, of course, there would be flows between many or all of the node pairs, not just one, and the above condition would have to be true for all node pairs for user equilibrium to exist.

Figure 25.4

Assignment / System-Equilibrium

- ◆ Let us distinguish between the *system-equilibrium* and the *user-equilibrium* approach.
- ◆ Imagine instead of everyone acting “selfishly”, we try to organize the flows on the network to minimize overall costs.
- ◆ Suppose the total cost function for operating this network was the sum of the cost of traversing each link multiplied by the flow on each link.
- ◆ These link flows may be composed of several *origin/destination* flows. C_{kl} is the link cost on link $k-l$ and F_{kl} is the link flow on link $k-l$.



$$\text{Total cost} = \sum_{\text{all } k,l} C_{kl} F_{kl}$$

The flow on link 3-2 may be composed of origin-destination flows 1-2, 3-2, 4-2, etc.

$$\text{Min } C_T = \sum_{\text{all } k,l} C_{kl} F_{kl}$$

Figure 25.5

Network Planning

- ◆ What can one use these analysis tools for in network planning?
- ◆ Understand what will happen if one modifies the network.
- ◆ For example, using this kind of formulation, one could choose which links to upgrade.
- ◆ So, we can experiment with our network models; add capacity to a link (or set of links) and see what happens to the flows. Was that investment cost-effective?

Networks and ITS

Real-Time Network Control

- ◆ Now we are considering ITS as a control mechanism for *tactically* controlling the transportation network in *real-time*.
- ◆ In order to have real-time ITS applications, one has to think more subtly about how these networks behave.
- ◆ For example, one would need to do a traffic assignment in this real-time environment; rather than having an origin-destination matrix for the entire day or for the rush-hour, one might have an origin-destination matrix for the network for every 15 minutes.

- ◆ So *in principle* you could predict -- given your time-varying origin-destination matrices and network assignment technique -- in real-time, where congestion on the network would occur.
- ◆ And you *might* -- given real-time information such as the sort that ITS provides -- be able to make control decisions that would allow you to optimize the flows on the network in real-time.
- ◆ You have strategies, such as changing speed limits, changing ramp-metering rates, providing routing instructions via variable-message signs or via in-vehicle displays, changing traffic signals, etc., available to you to control flow to some extent.

- ◆ Now, we have discussed two ways of using the network framework. One is planning-oriented and strategic; one is operations-oriented and tactical; both are based on the same fundamental network approach.
- ◆ The tactical problem is hard.
- ◆ It is a complex problem to solve *and* we need to solve it in real-time.

