



# **Travel Demand Modeling 101**

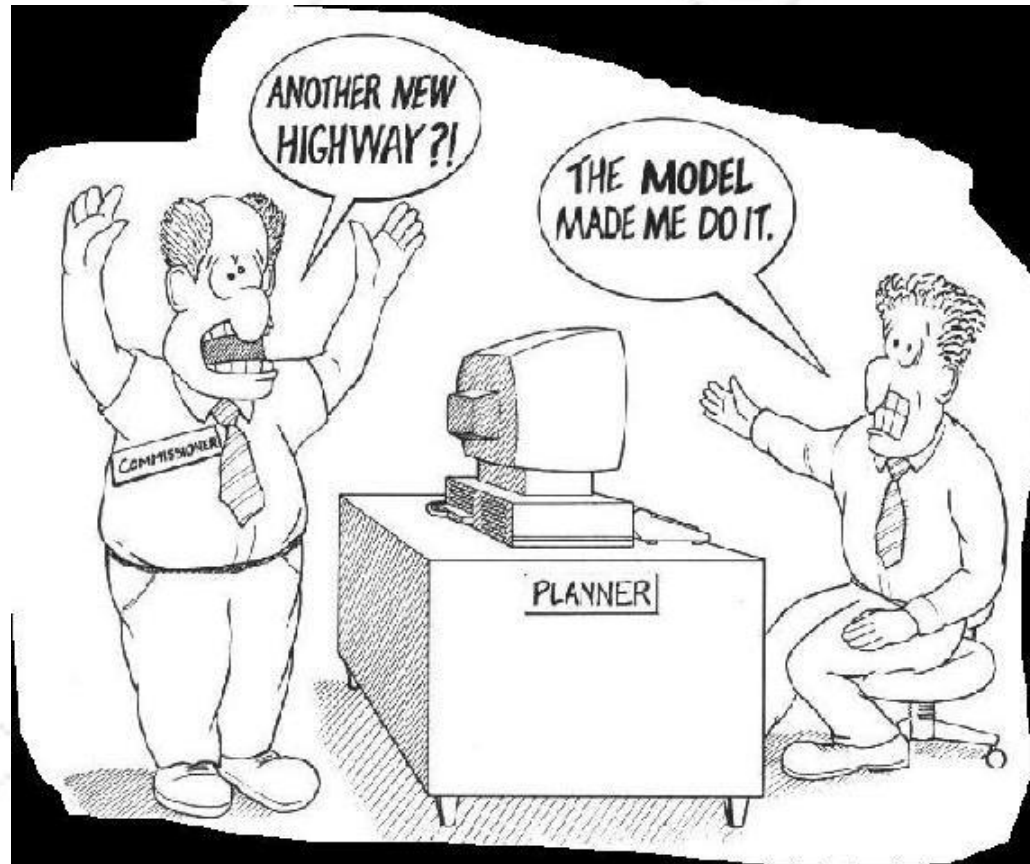
## **Overview**

For Kern COG

Regional Transportation Modeling  
Committee (TMC)

Adapted from Iowa State University  
presentation

# Why Are We Here Today?



# What is the Goal for Today?

- Introduction/Overview: Travel Demand Modeling
  - Why do we model travel demand?
  - How do we model travel demand?
  - Who uses model output?
  - Get the “Big Picture”!
  - Don’t worry about remembering everything today.
- Presentation designed to:
  - Educate MPO Policy and Technical Committee Members on the modeling process.

# Presentation Overview

- Introduction to Travel Modeling
- How to Build a Model
- The “Four” Steps
- Model Output
- Performance Measures
- Model Application
  - How Do We Use It?
  - Who Uses It?
  - Etc.

# What Is a Traffic Model?

- Typical Definition:
  - A computer program that runs mathematical equations using input data to replicate travel choices that individuals make.
- The output is a measure of future travel demand that is expressed in terms of future traffic volumes.
- Simply: A forecast of future travel.
  - Where are people traveling to and from.
  - What routes are they choosing to get there.

# Why Are Models Important?

- Models are the heart of Transportation Planning.
- They help to guide the development of Long-Range Transportation Plans.
- They help us determine how much traffic will be on our roadways in the future.
- They help us to understand the impact that development has on our transportation system.
- They guide future investment strategies.
- Models allow us to make informed decisions.

# What Are Travel Models Used For?

- Provide Decision Makers the best possible information about future needs.
- Determining where congestion may be in the future.
- Determining what projects will alleviate or minimize that congestion.
- Scenario analyses. (What ifs).
- How many lanes are we going to need?
- Determine traffic impact due to land use changes.
- Important to most all transportation projects.
- On-Road Mobile Source Air Emissions Analysis

# Building a Travel Demand Model

- What do we need to start?
- DATA!
  - Population (how many people do we have?)
  - Households (where do they live)
  - Employment (jobs, shopping, restaurants, recreation, etc.)
  - Schools (K-12, College locations)
  - Roadway Network (existing and future)
  - **Traffic Counts**
  - **Household Travel Characteristics**
- What causes us to travel each day and how do we get there.

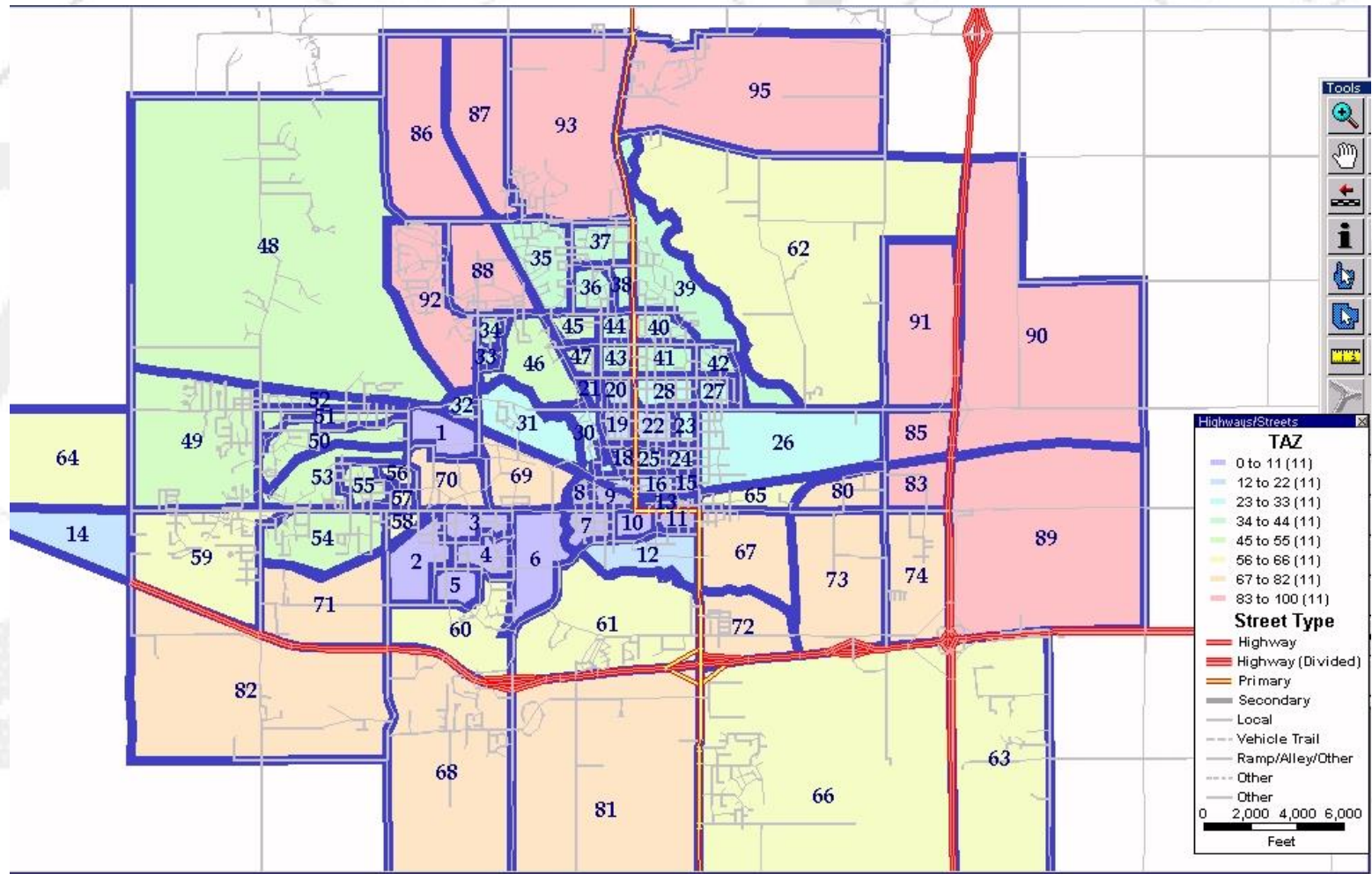
# How is our data organized?

- It is subdivided into special zones commonly referred to as:
  - Traffic or Transportation Analysis Zones
  - Zones (for short)
  - TAZs (for shorter)

# Traffic Analysis Zones (TAZ)

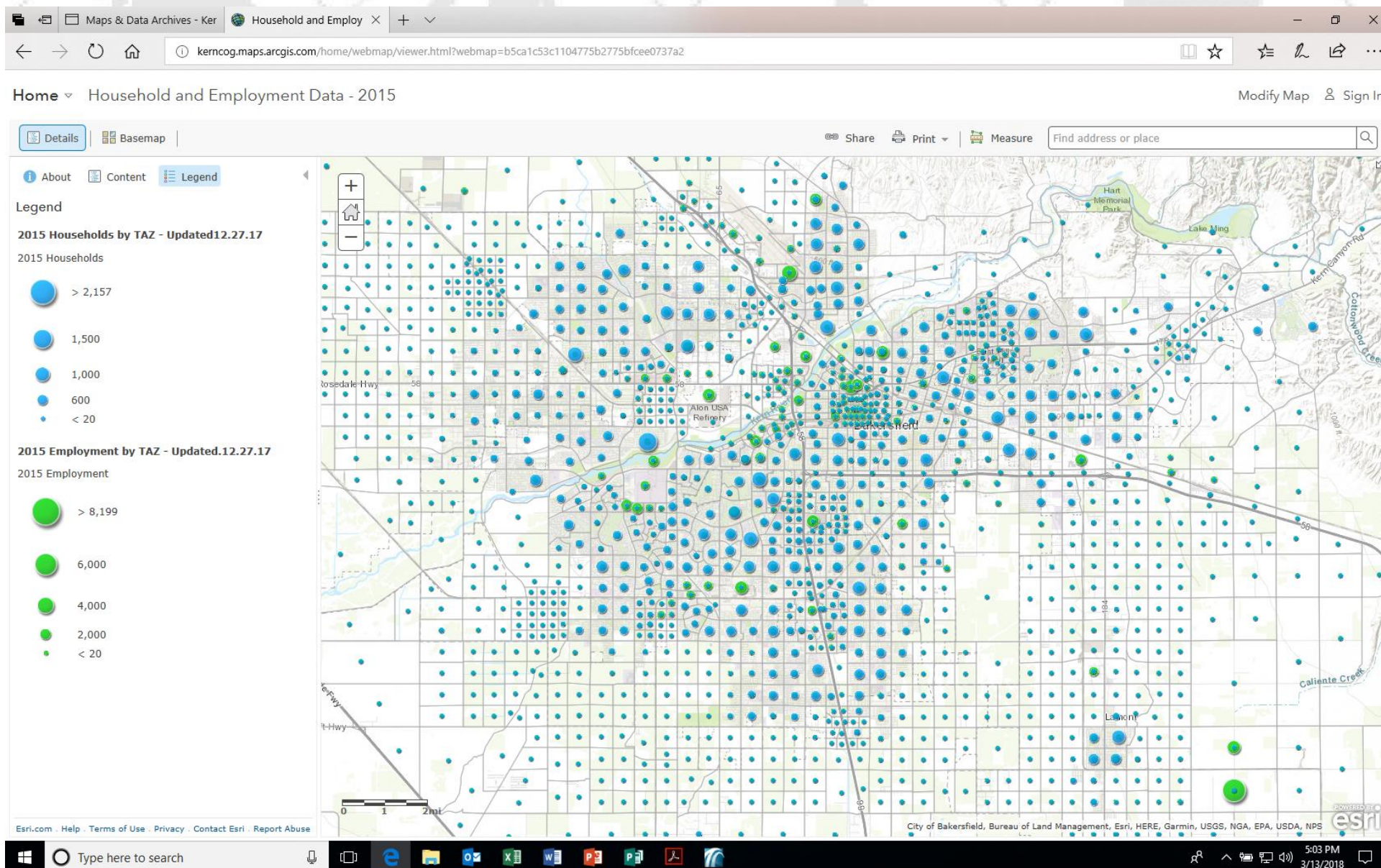
- What is a TAZ?
- Geographic Area where Data is Stored
  - Population, Employment, School Enrollment
- Similar to Census Geography (Aggregated)
  - In Kern, Subdivisions of Census Tracts

# Traffic Analysis Zones



# Kern's 2,000 Traffic Analysis Zones

<http://www.kerncog.org/category/data-center/data/>



# Traffic Analysis Zones (TAZ)

- TAZ Characteristics

- Approximately equal in size (smaller in downtown but larger on the periphery)
- Subdivisions of census tracts

# Traffic Analysis Zones (TAZ)

## ■ TAZ Characteristics

- TAZ boundaries are major roadways or physical barriers such as railroads, rivers, etc.
- Typically follow Census geography such as block or block group boundaries.
- Goal: replicate areas of **Origin** and **Destination** for trips being made.
  - Home to Work ; Home to Shopping ; Work to Shopping, etc.

# Model Input Data

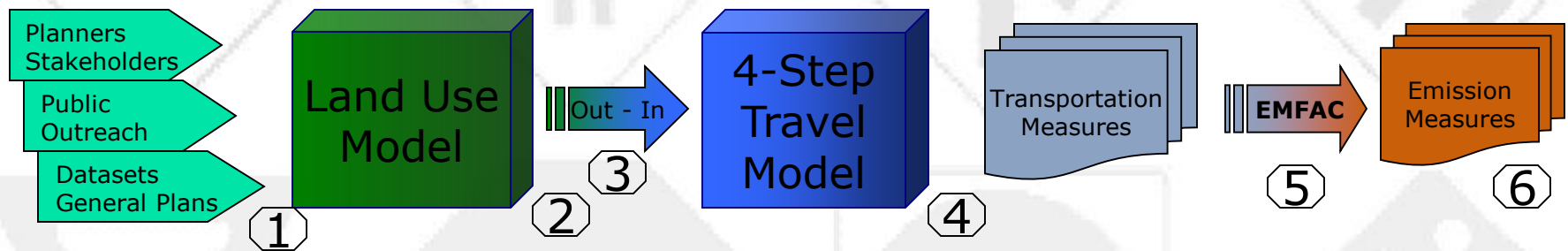
## ■ Socio-Economic Data

- Population
- Households/Dwelling Units
- Employment
- School Enrollment
- Vehicle Ownership
- Income Levels
- Land Use Characteristics / Zoning

# SE Data Table

	A	B	C	D	E	F	G	H
1	<b>Socioeconomic Data</b>			Year 2000				
2								
	TAZ	TOTAL	OCUPIED DWELLING	RETAIL	TOTAL	SERVICE		OTHER
3	2000	POP	UNITS	EMPL	EMPL	EMPL		EMPL
4								
5	1	0	0	1	526	525		0
6	2	2881	960	345	5552	5207		0
7	3	3032	1010	0	1447	1306		141
8	4	0	0	0	100	100		0
9	5	0	0	0	60	60		0
10	6	949	343	316	434	52		66
11	7	2667	422	189	362	93		80
12	8	822	251	0	27	26		1
13	9	2203	25	0	80	80		0
14	10	373	137	28	54	26		0
15	11	259	134	0	10	10		0
16	12	632	277	1	59	35		23
17	13	0	0	0	118	118		0
18	14	0	0	0	286	286		0
19	15	500	249	0	5	5		0
20	16	212	92	0	2	2		0
21	17	208	87	8	375	80		287
22	18	0	0	0	1114	30		1084
23	19	0	0	411	531	85		35
24	20	265	111	0	45	0		45
25	21	1408	768	269	433	45		119

# Kern Integrated Modeling Flowchart

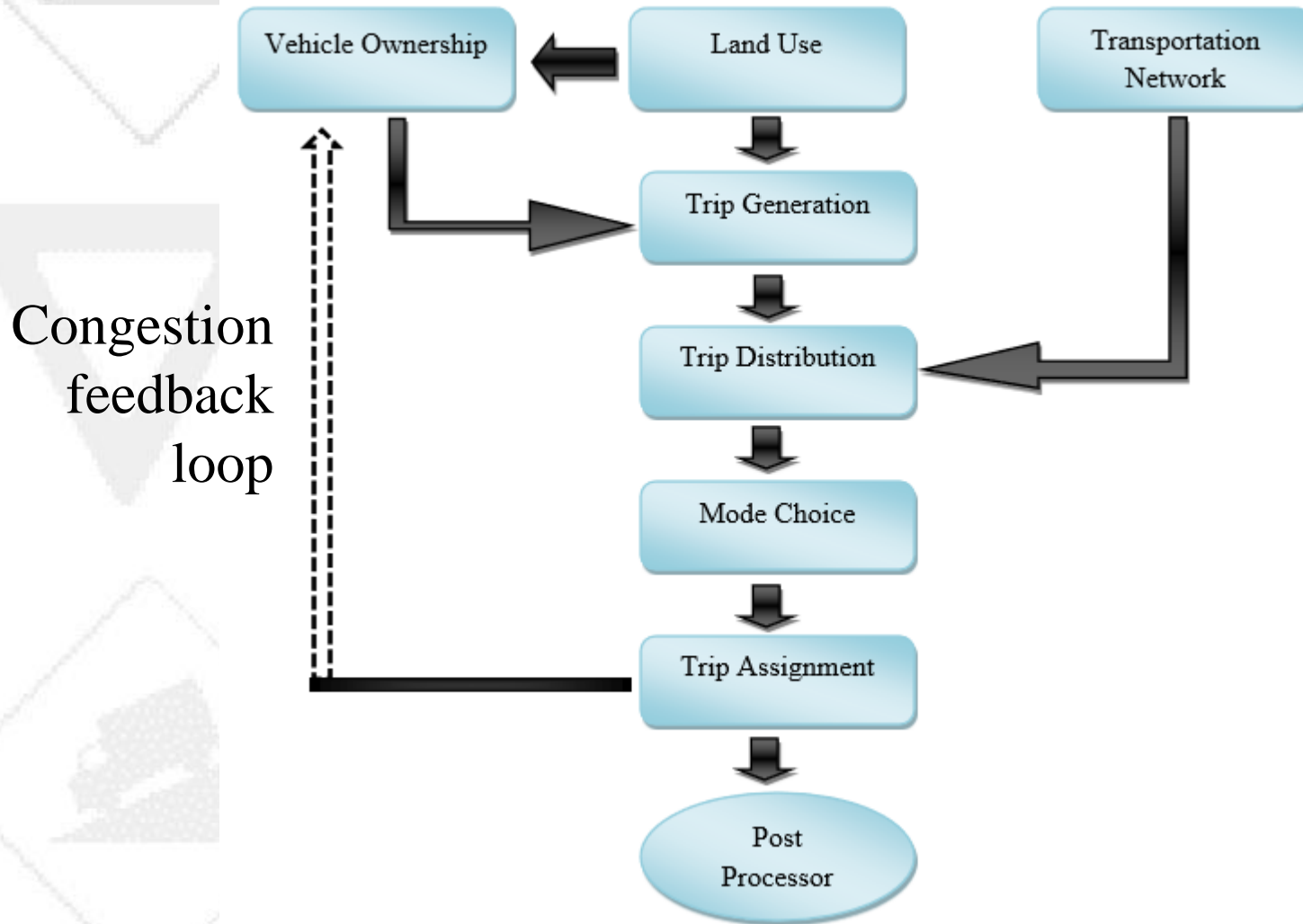


## Regional Transportation Plan Modeling

1. Inputs from Planners, Stakeholders, Public Outreach, Environmental Datasets, and current General Plans.
  - 1a. Planners, Stakeholders, and the Public develop Alternative, or Transit based strategies.
2. The Land Use Model **UPlan** allocates growth based on parameters, attractions like freeways, discouragements like public lands, and resources. It creates a GIS based conceptual growth map.
3. Uplan also outputs socioeconomic data by TAZ used as the input data for the Travel Model **Cube**.
4. Cube generates LOS maps, VMT, and other Transportation measures.
5. Cube output data is also used in **EMFAC** to generate Emission measures.
6. **The measures generated are reviewed, and relative comparisons between scenarios can be made.**

# Modified 4-Step Model Process

*Figure 2 – San Joaquin Valley Model Improvement Program: Model Components*



# The Four Steps



■ Trip Generation - How many trips?

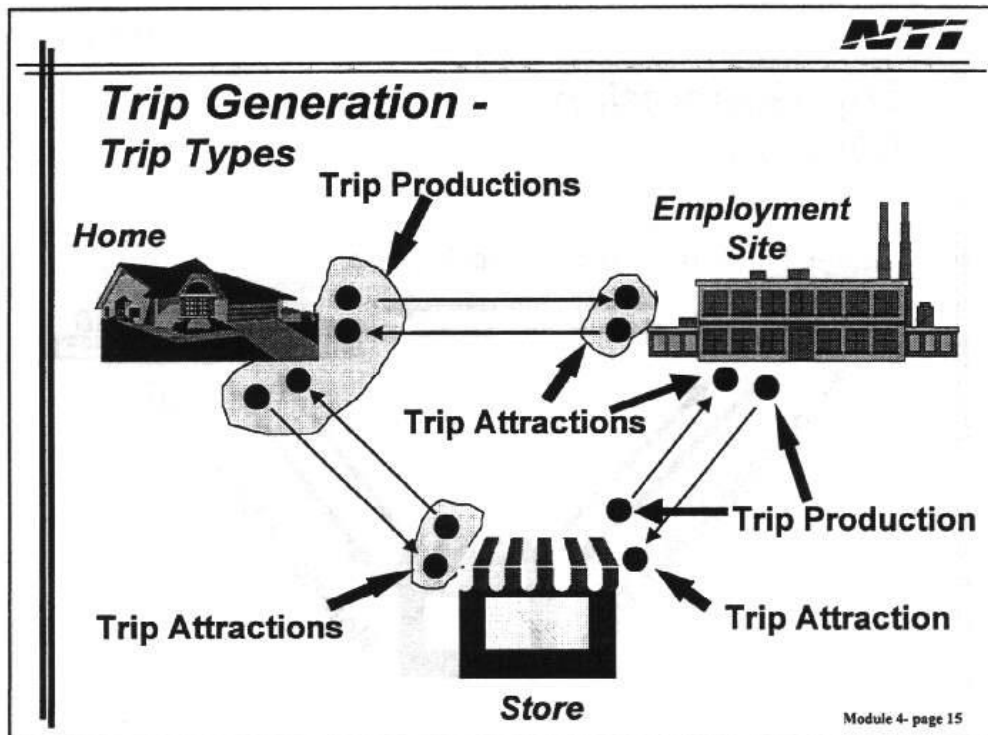
■ Trip Distribution - Where are they going?

■ Mode Choices - By what mode?

■ Trip Assignment - What path are they taking?

# Trip Generation (1<sup>st</sup> Step)

- Determines how many trips are being **Produced** from and **Attracted** to each TAZ?



**Productions and Attractions**

Buzz phrase: **P**s and **A**s

# Trip Generation Methods

- Cross Classification
  - Used to determine trip productions by TAZ
  - Persons per Household and Auto's Available
- Trip Rates Based on Activity Units
  - ITE Trip Generation Manual
    - Hospitals, Fast Food Restaurants, etc.
- Regression Equations
  - Used to determine TAZ attractions
  - Based on previously observed data.

# Special Generators

- Used for zones that have trip rates significantly different from standard trip rates.
  - Military Bases
  - Prisons

# Trip Purposes

- Trips are stratified into purposes:
  - **Home-Based Work** – Trips between home and work.
  - **Home-Based Other** – Trips between home and other places such as shopping and recreation.
  - **Non-home Based** – Trips that do not involve the home.
  - **External Trips** – Trips that enter/leave or travel through the study area.

# What Do We Get Out of Trip Generation?

- Trip Productions and Trip Attractions
  - By Traffic Analysis Zone
  - By Trip Purpose

# The Four Steps

- Trip Generation - How many trips?



- Trip Distribution - Where are they going?

- Mode Choices - By what mode?

- Trip Assignment - What path are they taking?

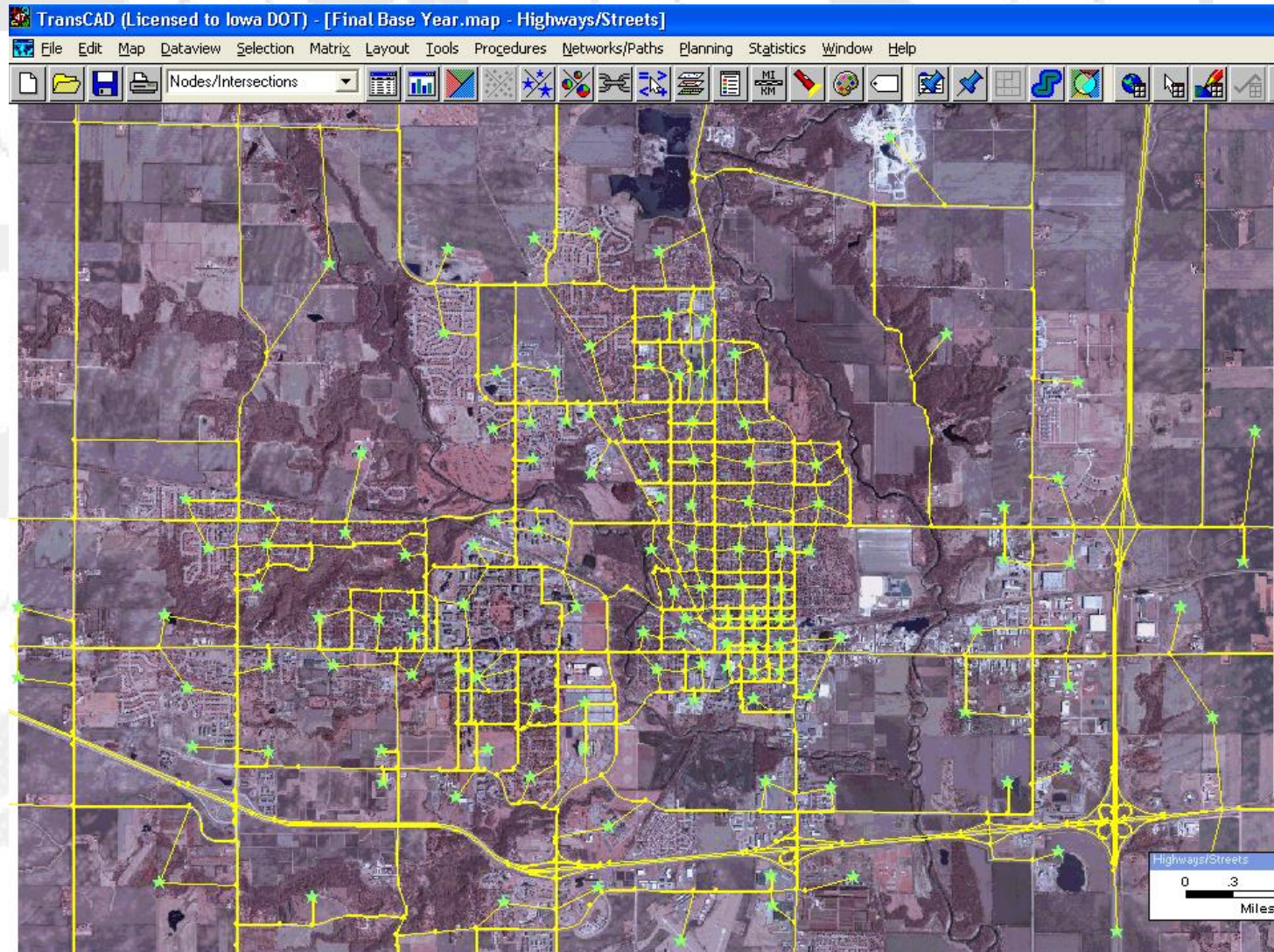
# Trip Distribution (2<sup>nd</sup> Step)

- Now we know how many trips are being produced from and attracted to each TAZ.
- But we don't yet know **where** the trips are going to or coming from.

# Roadway Network

- Before we can figure out how the trips are distributed between TAZs, we need to know how the zones are connected.
- Zones are connected by a network or roads.

# Roadway Network



# Roadway Network

**A system of nodes, links, and centroids that describe a transportation system.**

- 1. Node: intersections of roadway links.**
- 2. Links: Used to represent the street network (local collector roads are not included).**
- 3. Centroids: special node representing origin and destination of all trips for TAZ.**
- 4. Centroid connectors: special links that represent local roads and provide access between centroids and the network.**

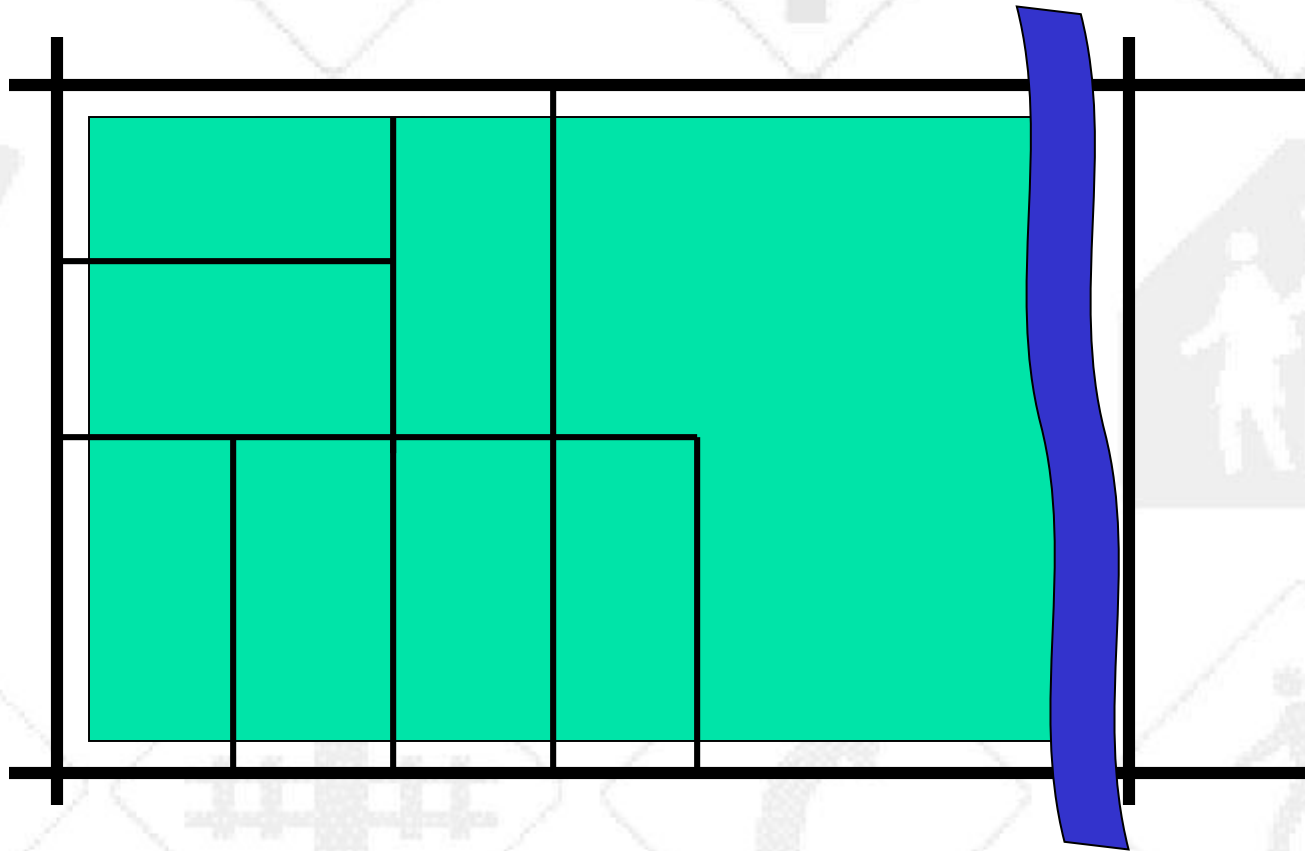
# Network Attributes

## ■ Transportation System

- Speed
- Capacity
- Direction
- Travel Time
- Functional Classification
- Traffic Counts

# Network Building

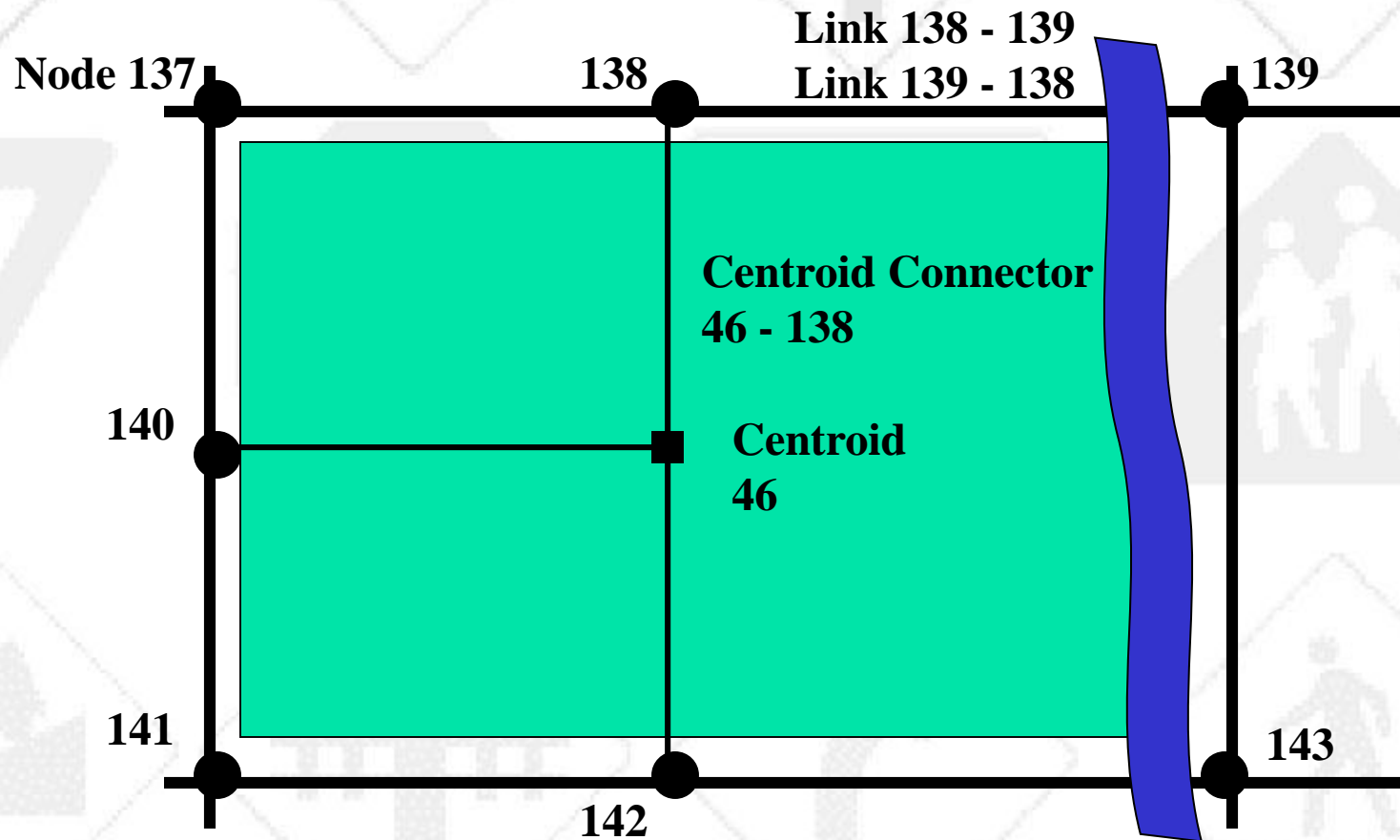
Actual Street System and River



Source: NTI

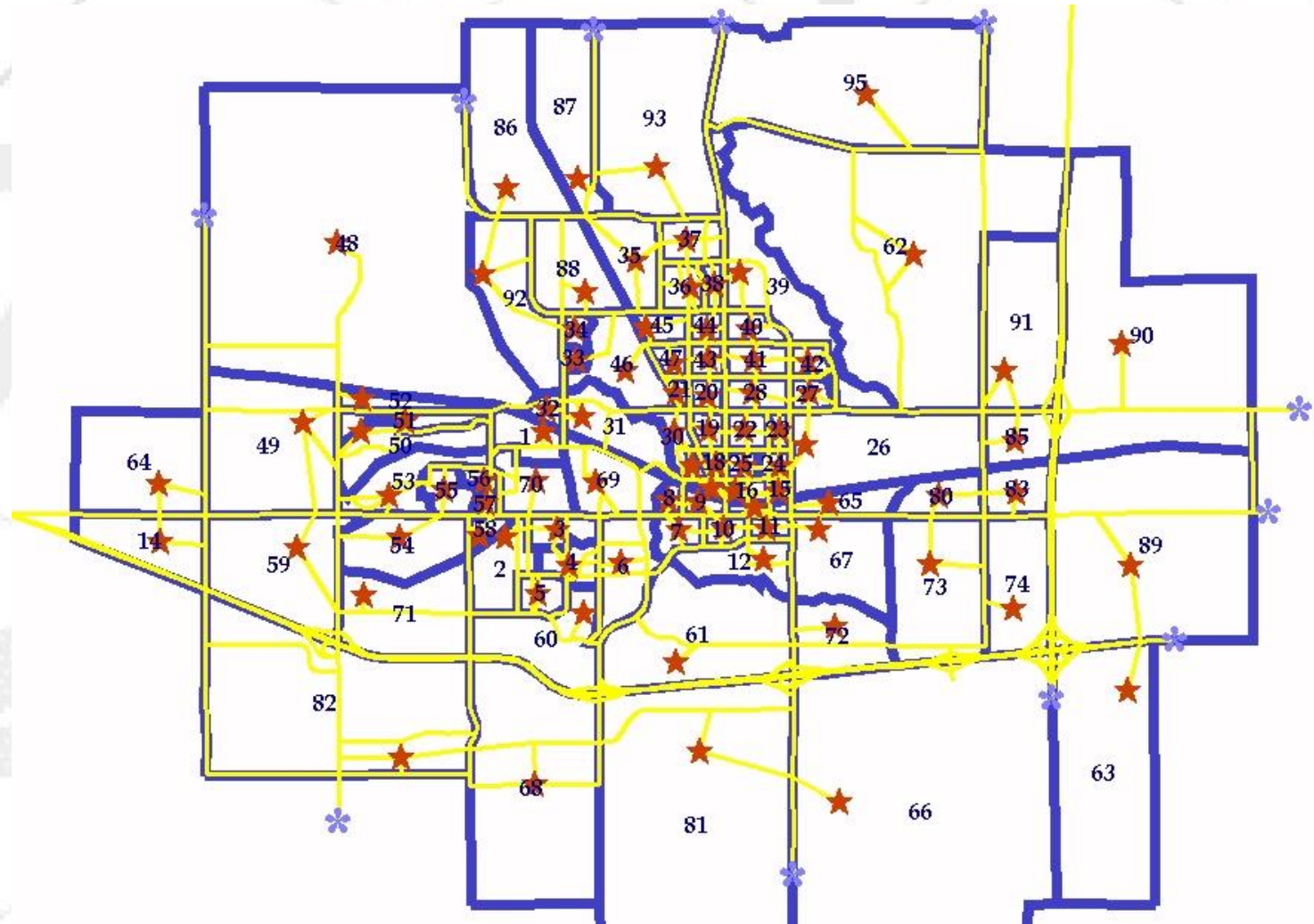
# Network Building

## Computer Street System

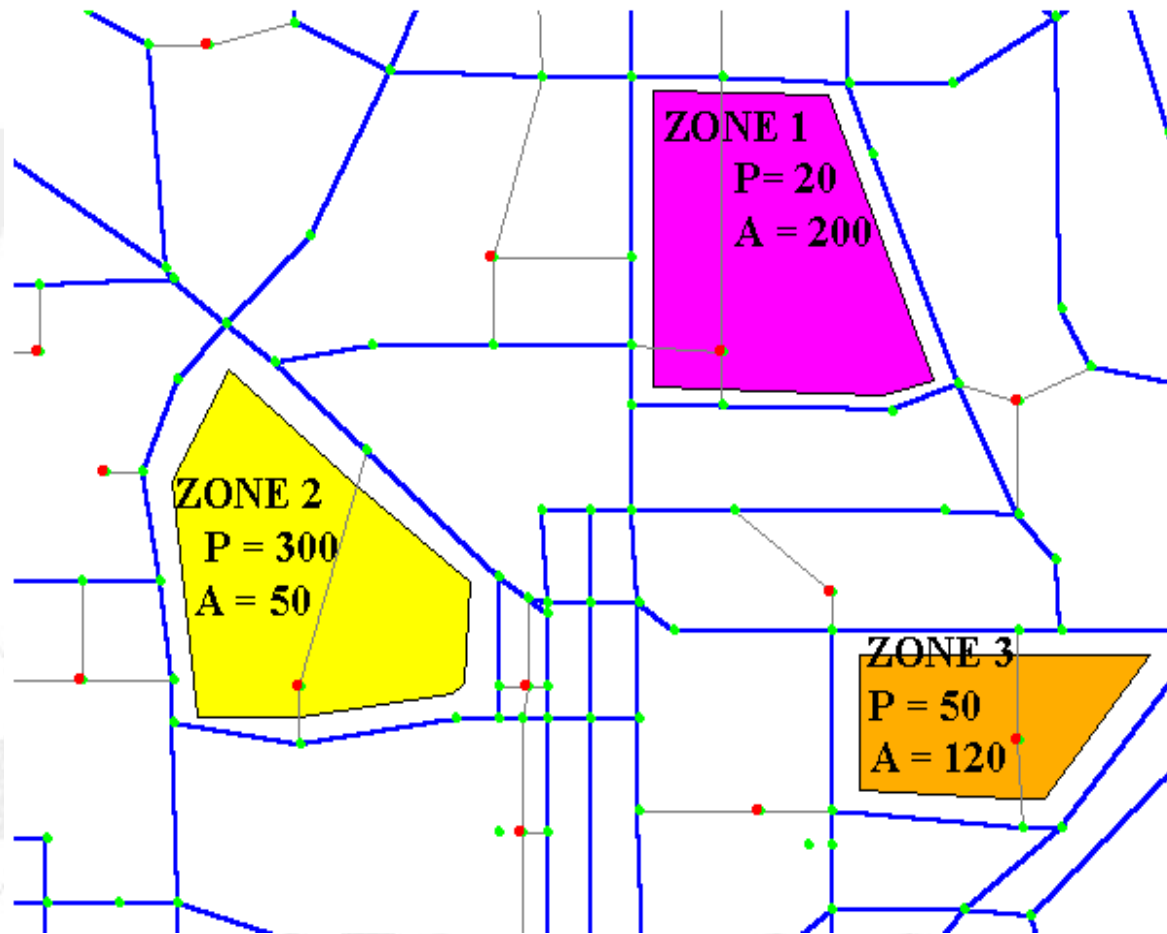


Source: NTI

# Centroids

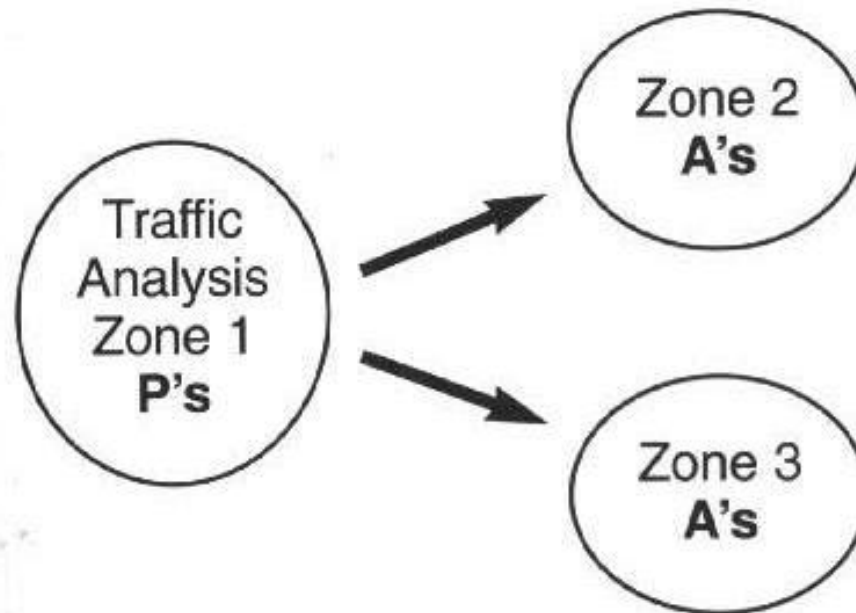


# Trip Distribution (2<sup>nd</sup> Step)



# Trip Distribution

- Determines where trips are going to and coming from.



# The Gravity Model

$$T_{ij} = P_i \times \left( \frac{A_j \times F_{ij} \times K_{ij}}{\sum_{j=1}^n A_j \times F_{ij} \times K_{ij}} \right)$$


Source: NTI

# The Gravity Model

- Analogous to Newton's Law of Gravitation!
- The number of trips between zones are directly proportional to the number of productions at the origin zone and attractions at the destination zone and;
- Trips are inversely proportional to a function of the “friction” between zones measured in distance.

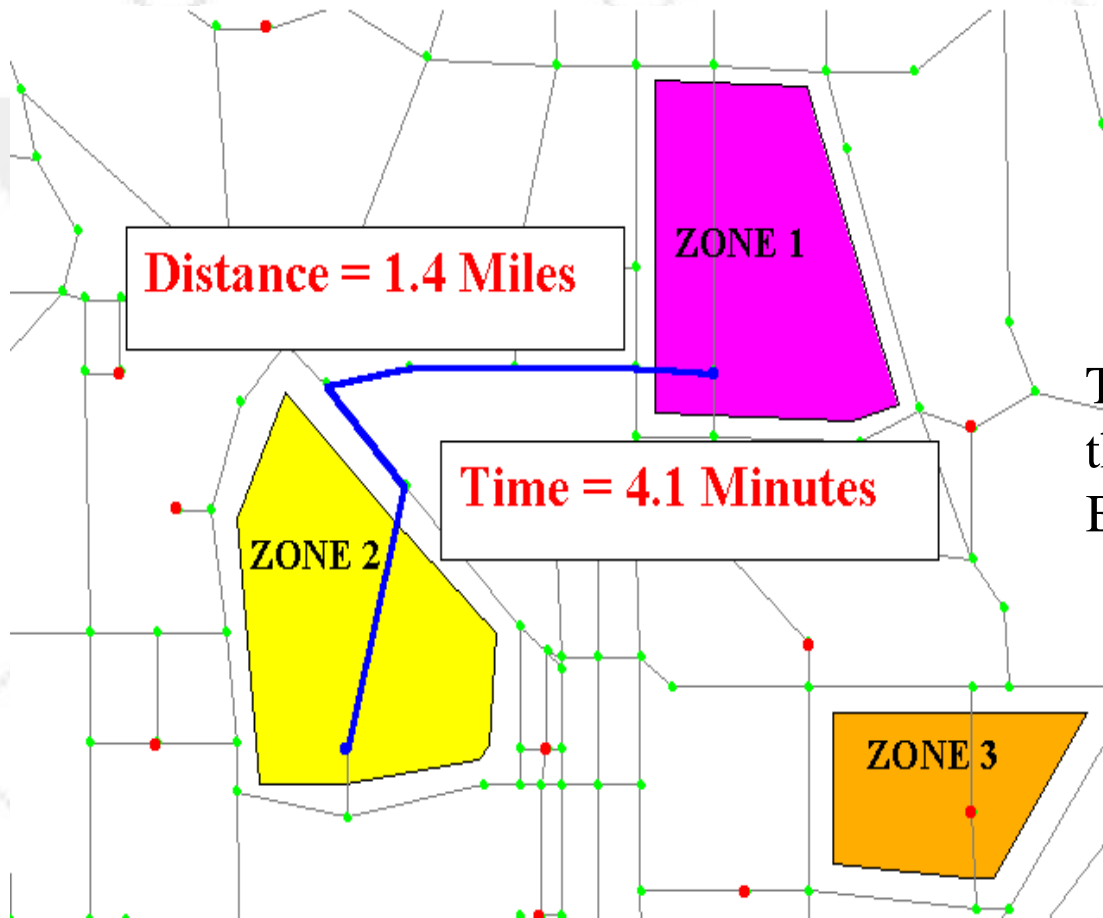
# Friction or Impedance Factors

- FF Inversely Proportional Time



	Min	HBW	HBO	NHB	Truck	E-I
GF	1 1	2300	5325	9000	7500	10000
GF	2 1	1850	4850	7500	7000	8900
GF	3 1	1500	4388	6000	6300	7800
GF	4 1	1200	3850	4000	5600	6400
GF	5 1	1000	3400	2800	5000	5000
GF	6 1	870	2725	1800	3000	3300
GF	7 1	730	1650	1100	1100	1900
GF	8 1	620	1000	700	760	1250
GF	9 1	530	653	450	500	870
GF	10 1	450	420	330	380	670
GF	11 1	370	320	240	270	530
GF	12 1	315	254	185	230	420
GF	13 1	275	196	140	195	345
GF	14 1	240	163	110	170	290
GF	15 1	215	140	85	150	240
GF	16 1	195	120	65	135	205
GF	17 1	175	101	50	120	170
GF	18 1	160	89	38	106	145

# Trip Distribution (Shortest Paths or Skim Trees)

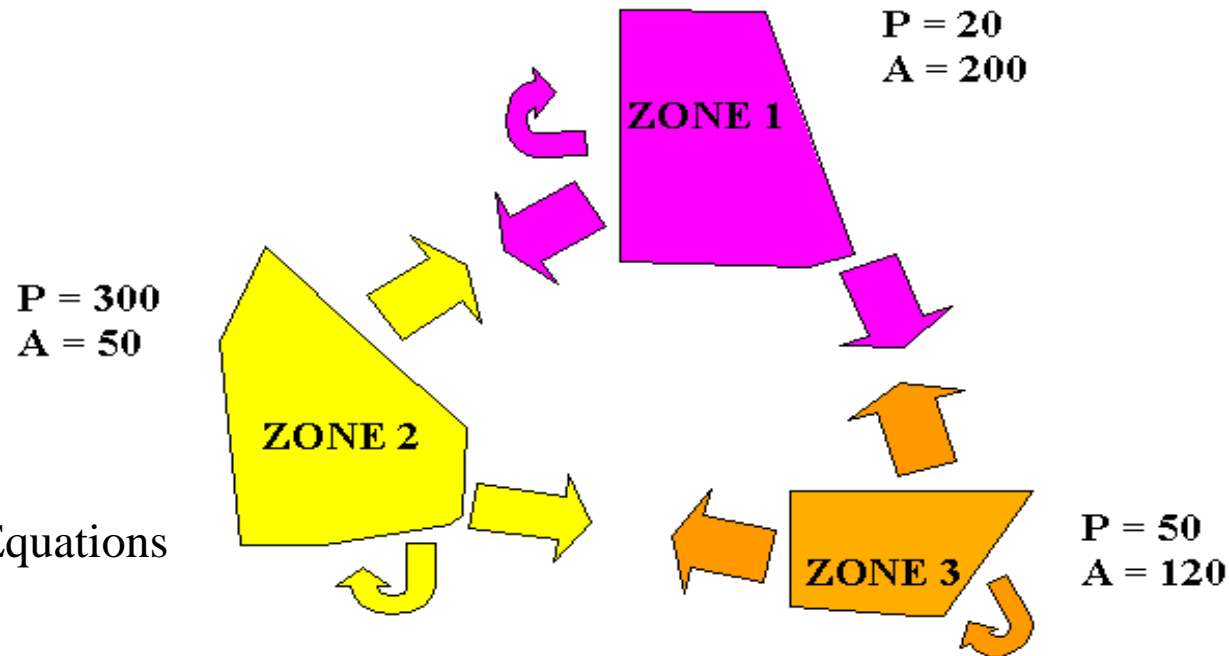


Travel Time (Minutes)	Distance Function $f(D)$
2.9	3.6
3.7	3.1
4.1	2.5
5.2	2.0

The Model Software Figures  
the Shortest Travel Time Paths  
Between All Zone Pairs

# Trip Distribution

Example that plugs in the numbers to the Gravity Model

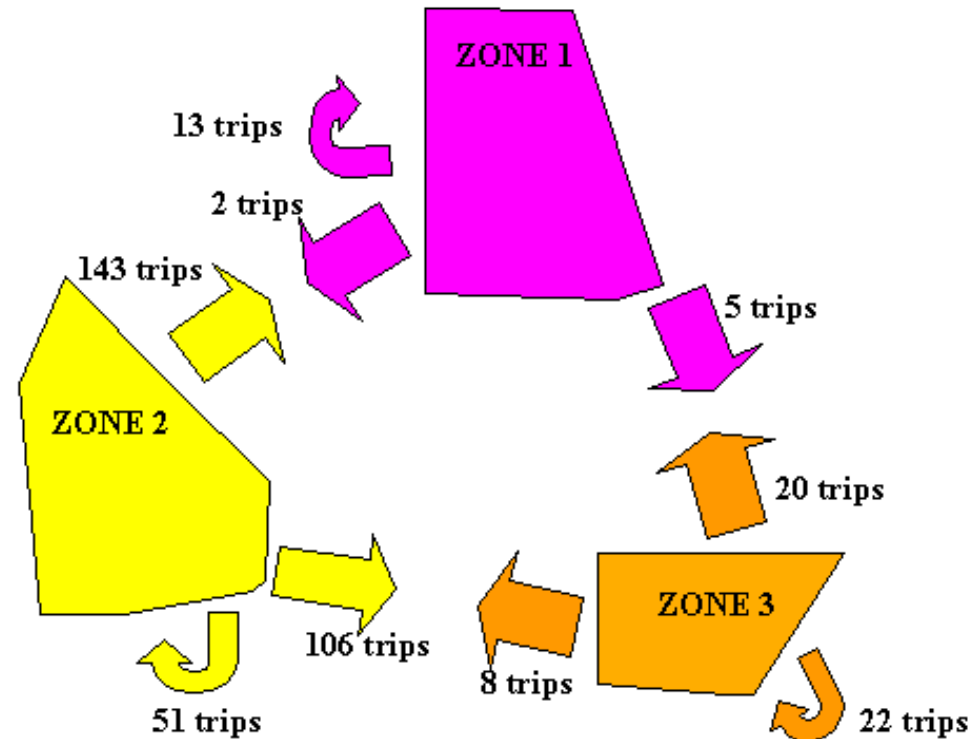


Gravity Model Equations

$$T_{1-1} = 20 * \frac{[200 * 3.6]}{[(200 * 3.6) + (50 * 2.5) + (120 * 2.0)]} = 13 \text{ trips}$$

$$T_{1-2} = 20 * \frac{[50 * 2.5]}{[(200 * 3.6) + (50 * 2.5) + (120 * 2.0)]} = 2 \text{ trips}$$

# Trip Distribution



Example Trip Table

Trip Matrix	Zone 1	Zone 2	Zone 3	Total Productions
Zone 1	13	2	5	20
Zone 2	143	51	106	300
Zone 3	20	8	22	50

# Trip Distribution: Trip Matrix

TransCAD (Licensed to Iowa DOT) - [Matrix1 - Output Matrix (QuickSum)]

File Edit Map Dataview Selection Matrix Layout Tools Procedures Networks/Paths Planning Statistics Window Help

QuickSum


	1	2	4	5	6	7	8	9	10	11	12	15	
1	4.37	5.86	2.62	6.92	1.84	1.50	0.64	2.98	6.76	0.89	6.16	4.12	4.2
2	26.23	63.09	8.81	26.12	14.51	4.52	1.88	26.11	75.00	6.88	43.80	41.04	43.9
4	16.74	34.52	4.66	12.13	12.54	2.32	0.95	18.44	55.65	5.01	31.17	29.49	31.0
5	8.34	25.24	9.57	29.88	5.20	5.37	2.10	8.35	19.62	3.20	24.05	12.32	11.9
6	1.84	3.19	1.93	4.30	1.34	0.98	0.40	1.78	4.31	0.59	4.05	2.37	2.3
7	11.60	19.98	2.76	6.92	7.74	2.23	0.91	15.90	52.40	4.32	26.40	23.71	26.3
8	4.24	7.44	1.07	2.63	2.68	0.87	0.35	6.76	17.54	1.45	8.74	8.66	9.0
9	7.52	12.57	3.04	7.54	4.54	2.23	1.09	11.38	32.52	2.80	17.06	15.06	17.0
10	6.75	11.72	5.94	14.83	4.30	4.77	1.84	9.45	21.76	2.82	19.25	11.13	12.3
11	5.07	8.64	1.37	3.50	3.40	1.02	0.38	7.45	23.28	2.68	15.25	14.13	14.2
12	27.87	50.13	9.90	25.40	18.62	7.71	2.81	38.98	122.14	14.18	92.91	69.62	72.0
15	4.88	8.84	3.84	9.90	2.82	2.80	1.16	5.86	14.51	2.38	15.17	12.81	10.9
16	5.09	8.76	3.73	9.45	2.85	2.81	1.19	6.39	16.35	2.22	14.52	10.49	11.9
17	3.96	6.56	2.00	5.01	2.20	1.49	0.69	5.11	13.18	1.44	9.28	7.77	9.2
18	4.43	7.30	1.12	2.85	2.47	0.83	0.36	5.97	18.49	1.66	10.01	10.79	13.2
19	12.94	19.96	2.55	6.65	7.11	1.76	0.76	16.33	50.52	4.39	26.44	29.59	34.7
20	9.60	14.33	1.79	4.69	5.07	1.22	0.52	11.45	35.30	3.09	18.72	20.76	23.4
21	7.31	10.07	1.27	3.34	3.73	0.74	0.33	7.84	23.84	2.04	12.30	13.98	15.4
22	13.76	21.86	2.78	7.26	7.64	1.95	0.84	17.65	54.54	4.78	28.94	34.56	36.7
23	15.16	23.17	9.42	24.62	8.46	6.05	2.64	16.07	41.47	5.46	35.87	32.35	28.9
24	6.60	10.63	1.87	4.91	3.75	1.29	0.55	8.25	24.79	2.63	15.76	22.17	17.0
25	11.29	18.27	2.92	7.63	6.38	2.16	0.92	14.66	44.67	4.49	26.96	30.32	33.8
26	20.46	32.78	5.15	13.64	11.78	3.50	1.46	25.20	76.05	7.75	47.44	57.81	51.2
27	11.21	17.69	2.39	6.39	6.23	1.63	0.69	13.38	40.61	3.96	24.41	28.85	26.4
28	13.36	20.72	2.62	6.92	7.29	1.79	0.76	16.26	49.86	4.47	26.86	32.25	32.7
29	3.60	5.65	0.84	2.12	2.02	0.61	0.28	4.88	13.18	1.17	7.10	7.74	9.0
30	7.95	11.97	1.38	3.60	4.32	0.92	0.41	9.74	28.38	2.45	14.77	16.66	18.3
31	0.50	0.62	0.30	0.75	0.22	0.18	0.08	0.35	0.80	0.11	0.73	0.49	0.9
32	0.82	1.04	0.49	1.25	0.35	0.28	0.12	0.56	1.27	0.17	1.17	0.78	0.8
33	21.08	31.31	4.09	10.90	9.48	2.54	1.05	18.97	54.97	4.93	31.12	31.94	34.7
34	16.38	24.17	2.83	7.60	7.50	1.69	0.70	14.93	43.73	3.83	23.91	25.33	27.0
35	35.40	51.18	5.56	15.25	17.09	3.24	1.39	34.80	106.07	9.26	57.15	62.92	66.8
36	7.49	11.45	1.50	4.07	3.75	1.03	0.43	8.10	24.45	2.23	14.02	14.59	15.0
37	23.76	36.04	4.27	11.48	12.26	2.85	1.20	26.33	80.07	7.15	44.56	47.83	51.0

MatrixView: 143 rows by 143 columns

Network: d:\...ear\ames2000binarynetwork.net

start OAmes Microsoft PowerPoint ... TransCAD (Licensed to ... 10:11 AM

# The Four Steps

- Trip Generation - How many trips?
- Trip Distribution - Where are they going?
-  ■ Mode Choices - By what mode?
- Trip Assignment - What path are they taking?

# Mode Split (3<sup>rd</sup> Step)



# Mode Choice Models

- Mode Choice Models model the travelers choice of which mode to take, ie car, transit, walk, etc.

# Mode Choice Models

- Kern's Mode share is approximately:
  - Transit: 0.5%
  - Non-motorized: 13%
  - Single Occupancy Vehicle (SOV): 38%
  - High Occupancy Vehicle (HOV) 2+ pers: 47%

# External Trip Estimation

- Good idea of internal travel (planning area)
- What about trips that leave the area?
- External Station Description
  - Somewhat similar to TAZ
  - Origin and Destination of Trips
- Two kinds of trips.
  - External to External
  - Internal to External or External to Internal

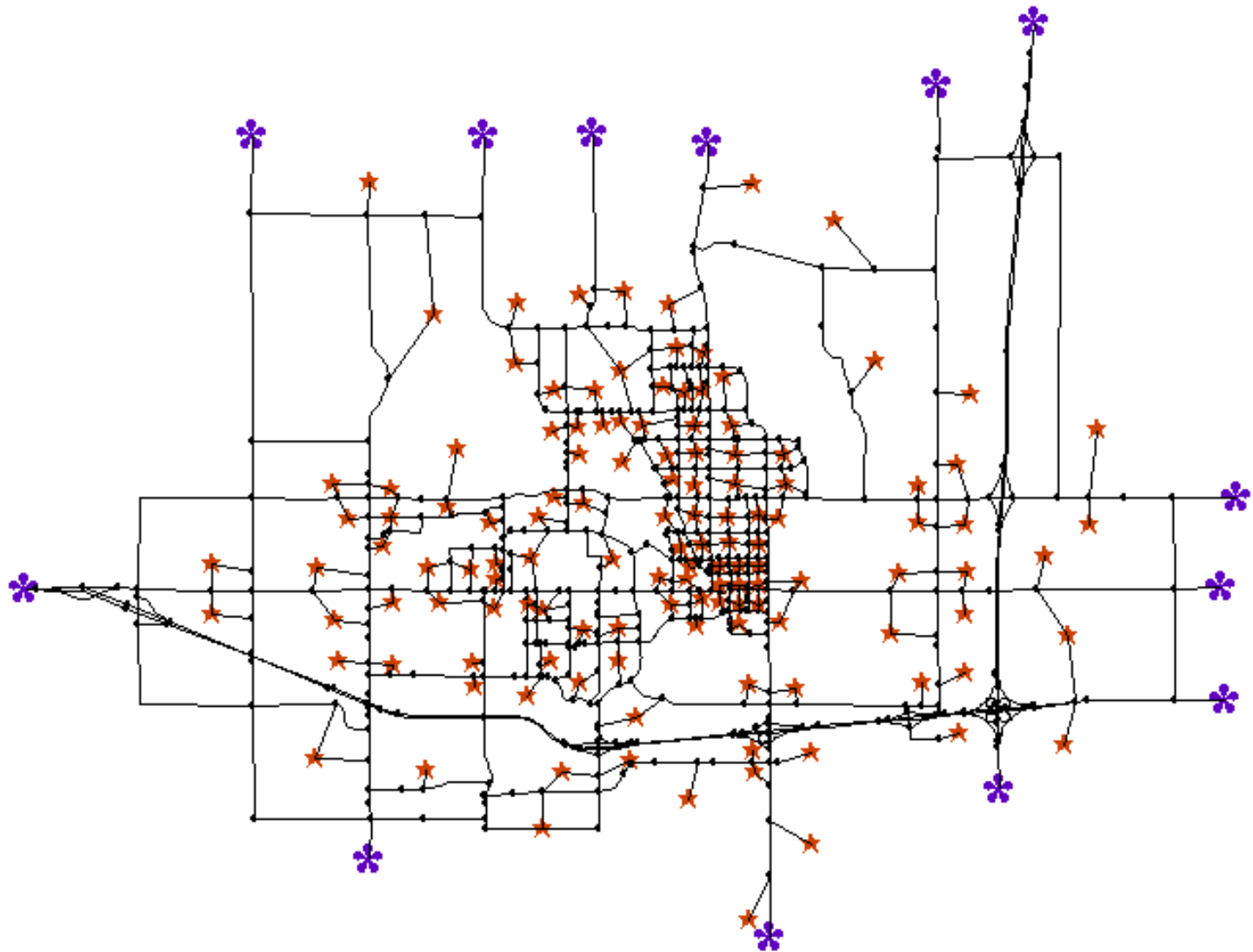
# External Trip Estimation

- NCHRP 365 Process – Travel Estimation Guide
- Urban Areas approximately 50,000 in Pop.
- 1<sup>st</sup> Step: Determine Through Trip Percentages
  - Larger Urban Areas have more EI/IE
- Through trip % based on:
  - ADT (cordon volume)
  - Size of Area
  - Functional Class of Facility
  - Vehicle Makeup (% trucks) (propensity for through trip)

# External Trip Estimation

- 2<sup>nd</sup> Step: Distribution of EE Trips
  - Modlin equations to accomplish this.
  - Discuss in detail later in the semester.
- Result is EE matrix
- 3<sup>rd</sup> Step: EI/IE Productions and Attractions
  - Involved process to be covered in detail later.
  - EI/IE trips get distributed with the Gravity Model. EE trip matrix already distributed.

# External Stations



# The Four Steps

- Trip Generation - How many trips?
- Trip Distribution - Where are they going?
- Mode Choices - By what mode?
- Trip Assignment - What path are they taking?

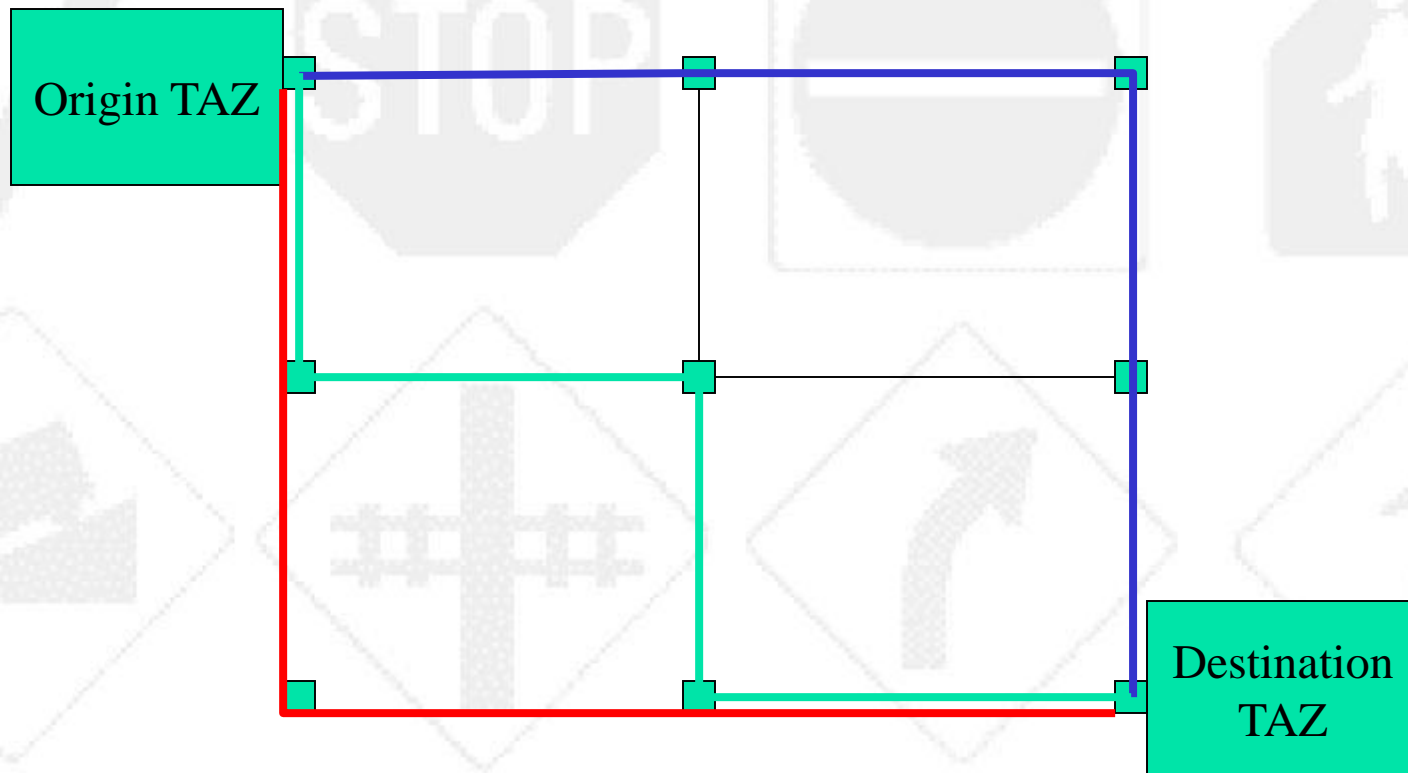


# Traffic Assignment

- Now it is known how many trips are going between each zone pair.
- What are we missing?

# Trip Assignment (4<sup>th</sup> Step)

- Determining the path a trip will take between the origin and destination TAZ.



# Traffic Assignment

- Now we know how many trips there are, where they are going and the mode they are using, but not yet the path they will take.
- Several assignment methods available
  - Uncongested - Shortest Path
  - Human Behavior - Stochastic
  - Congestion – Capacity Restraint
  - Equilibrium – No trip can decrease its travel time by taking an alternate route.

# Trip Assignment – Path Selection Criteria

The Path a Trip will most likely take between two zones is based on:

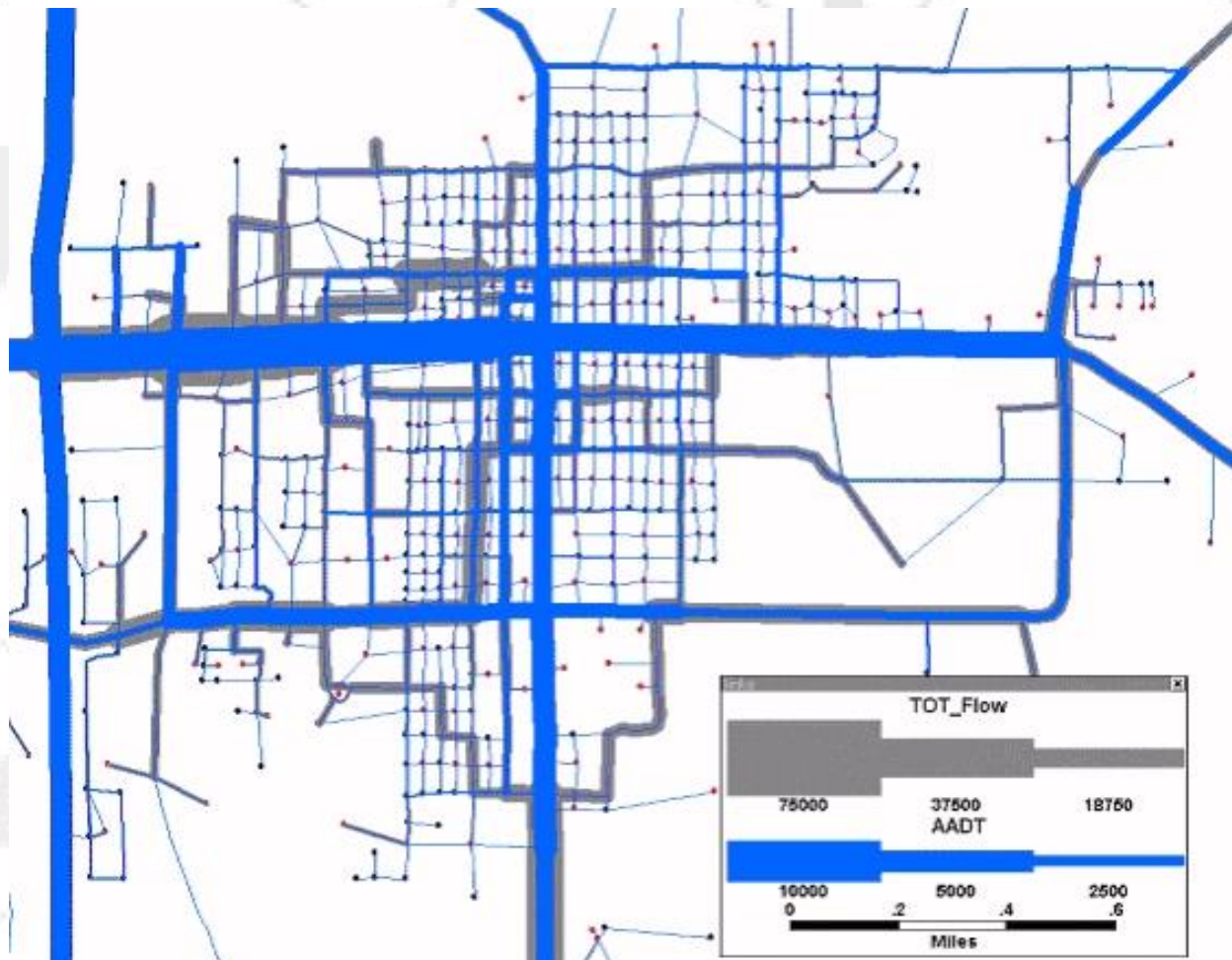
- Travel Time or Friction
- Congestion or V/C Ratio
- Turn Penalties & Prohibitions
  - 15 second penalty for left turns, no right turns, etc.

# Traffic Assignment Outputs

- Link volumes and speeds
- Turning movements at intersections
- Estimates of Regional VMT (vehicle miles traveled) and VHT (vehicle hours of travel)
- Congestion measures (V/C Ratio)



# Loaded Network Flows



# Validation and Model Errors

- Steps to Obtain a Reliable Model
  - Model Estimation
  - Model Calibration
  - Model Validation (Traffic Counts)
  - Model Application
  - Reasonableness Checks
  - Sensitivity Checks

# Steps to Obtain a Reliable Model

- Model Estimation

- Statistical estimation of model parameters

- Trip Generation Rates
    - Trip Length Frequency Distribution

- Model Calibration

- Adjustment of model parameters until predicted travel matches observed travel

# Steps to Obtain a Reliable Model

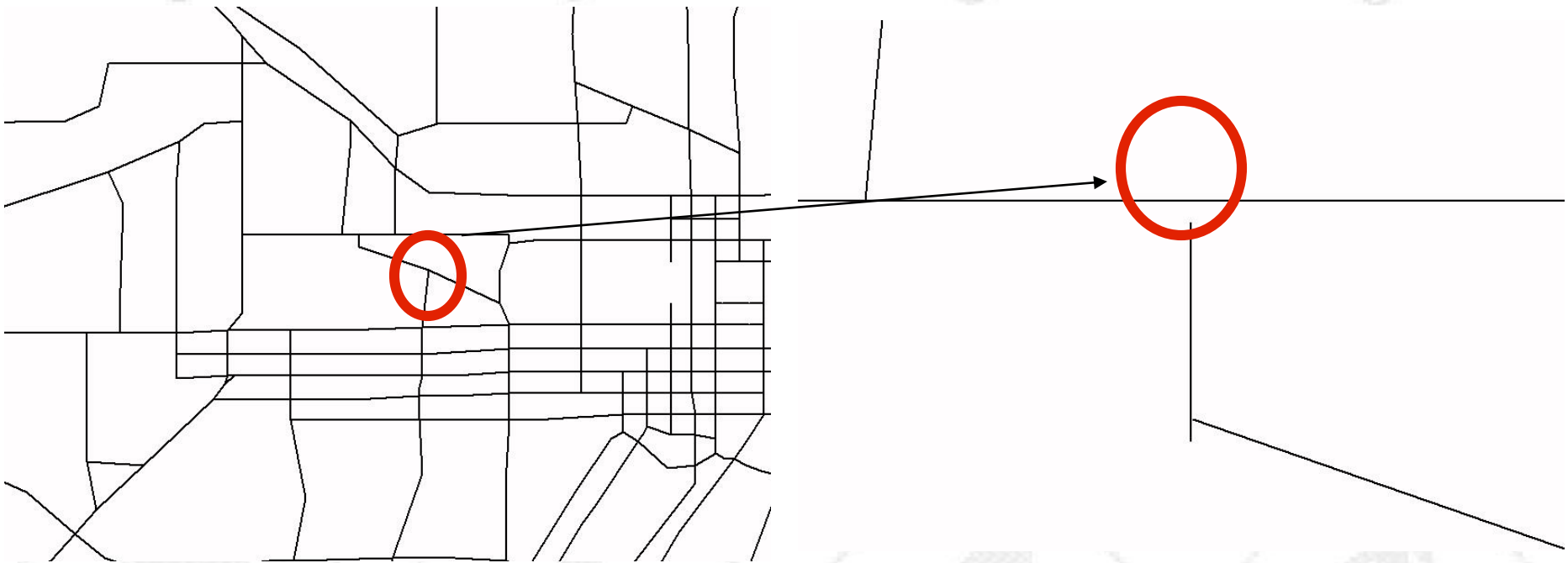
- Model Validation

- Checking the model results against observed data and adjusting the parameters until model results fall within an acceptable range of error.

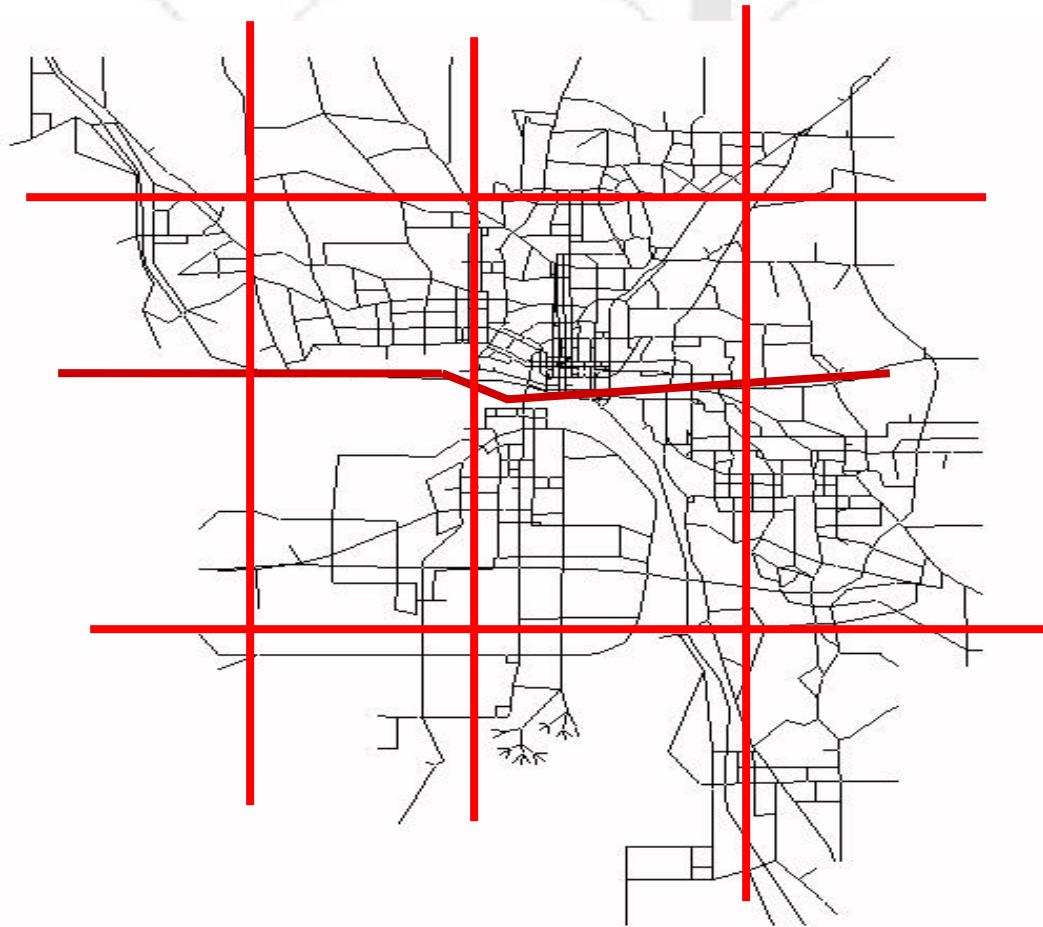
- Model Application

- Checking the reasonableness of future year traffic projections
- Testing the sensitivity of the model to system or policy changes

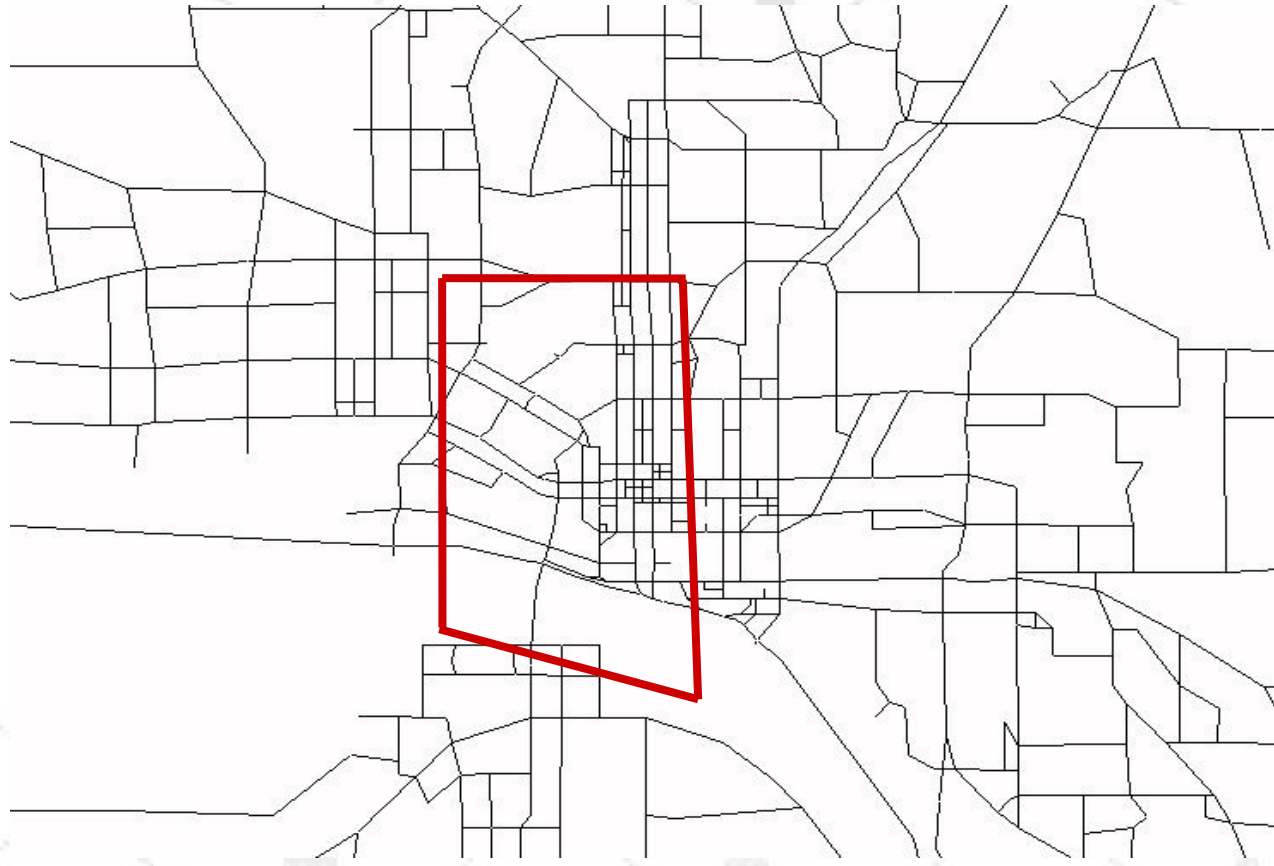
# Network Connectivity Check



# Screen Line



# Cordon Line

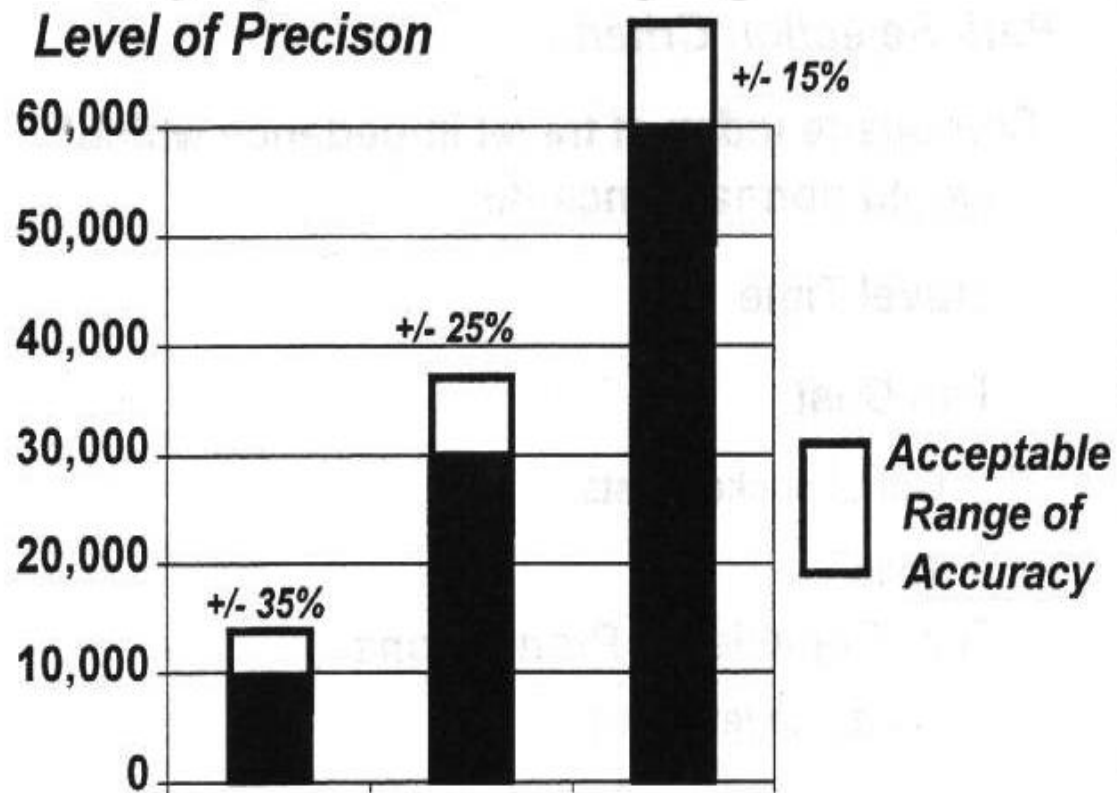


# Cut Line

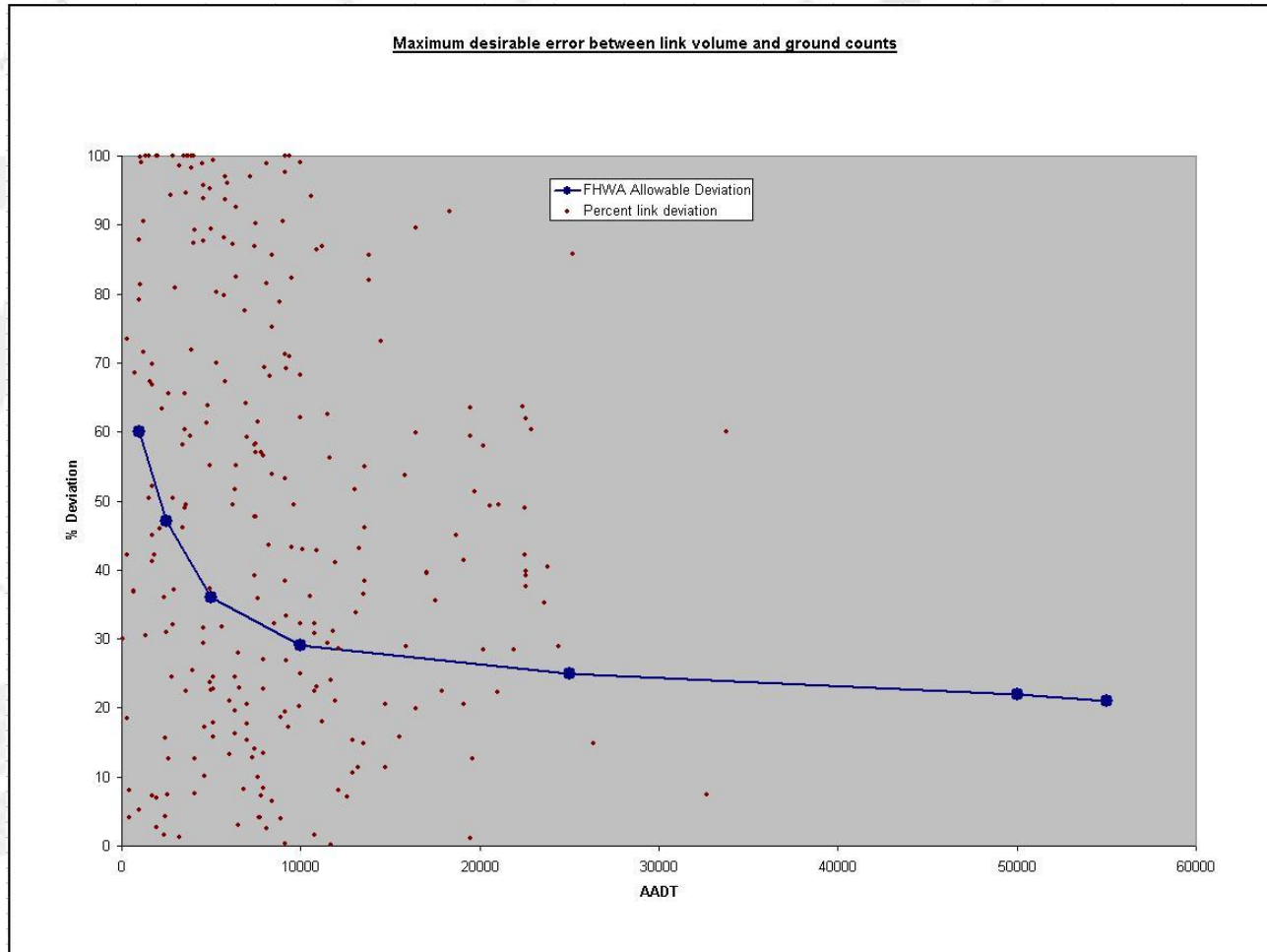


# Acceptable Ranges of Error

ADT



# Acceptable Ranges of Error (% deviation)



# Two Models (Base and Future)?

- Two Time Frames (Two Models)
  - Base Year
  - Forecast Year
- Base Year Model
  - Calibrated to Match Traffic Counts
  - Replicates Existing Conditions
  - Gives Confidence for Future Projections

# Two Models?

- Forecast or Planning Horizon Year
  - At least 20 Years into the Future
  - Forecast Population, Employment, etc.
  - Includes Planned Roadways and Development
- Trend for Interim Year Scenarios
  - Base, 5, 10 and 20



Questions?

Documentation:

[http://www.kerncog.org/category/  
data-center/transportation-  
modeling/](http://www.kerncog.org/category/data-center/transportation-modeling/)