IRA A. FULTON SCHOOL OF ENGINEERING

Leading engineering discovery and innovative education for global impact on quality of life.

An Application of TRANSIMS to the Analysis of Multimodal Corridors in the Greater Phoenix Metropolitan Area

FHWA Contract DTFH61-08-C-00018
Project Manager: Brian Gardner, FHWA

S. Ellie Ziems, Bhargava Sana, Ram Pendyala

School of Sustainable Engineering and the Built Environment

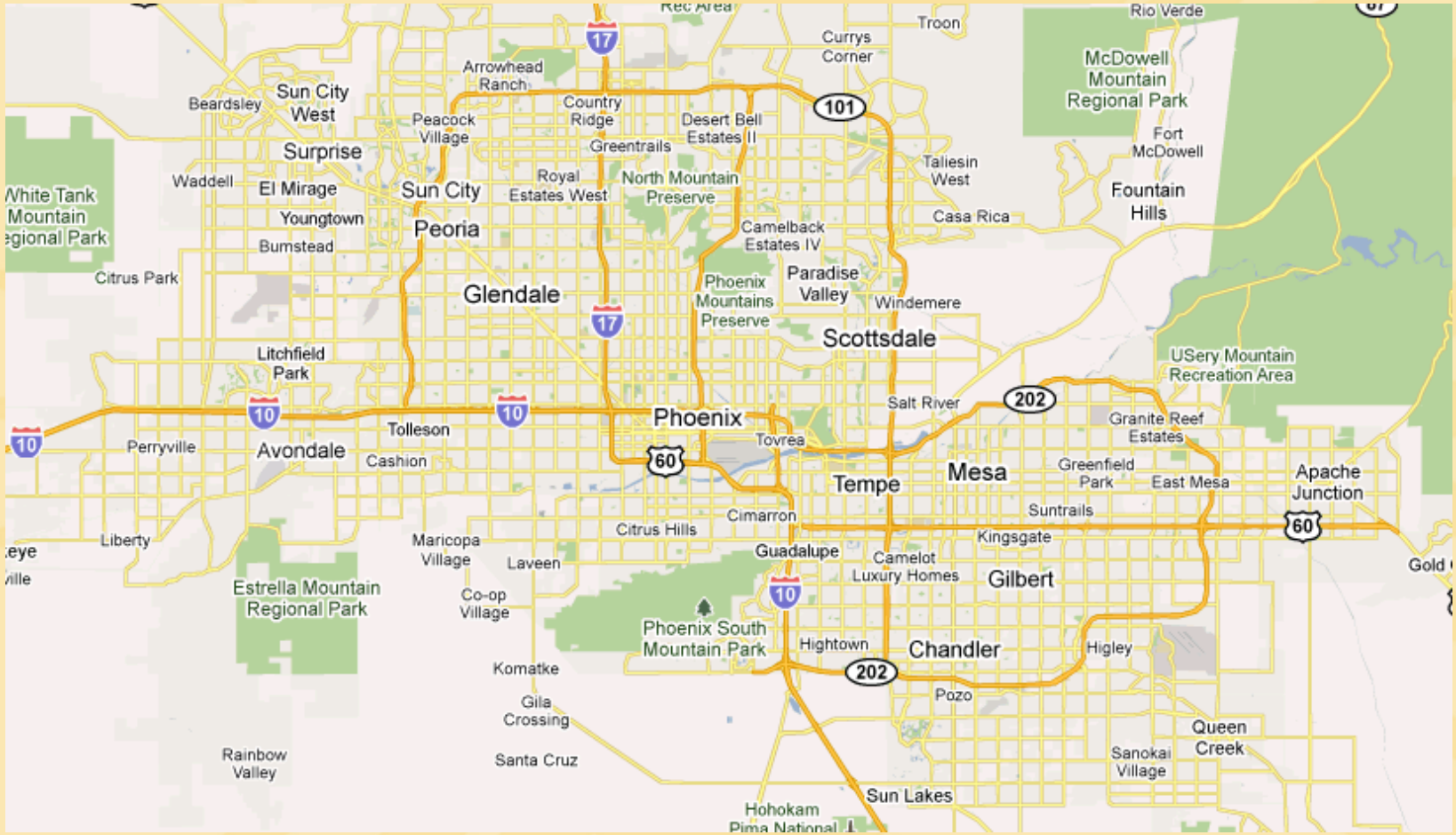
TRANSIMS: Applications and Development Workshop
April 8-9, 2010; Chicago, IL

ASU Arizona State University

Outline

- Background
- Project Objectives
- Project Approach
  - Highway Network
  - Transit Network
  - Light Rail Subarea
  - Travel Demand Input
  - Simulation
  - Ongoing Work
- TRANSIMS Documentation
- Upcoming Activities

Welcome to the Greater Phoenix Area



Ira A. Fulton School of Engineering
ARIZONA STATE UNIVERSITY

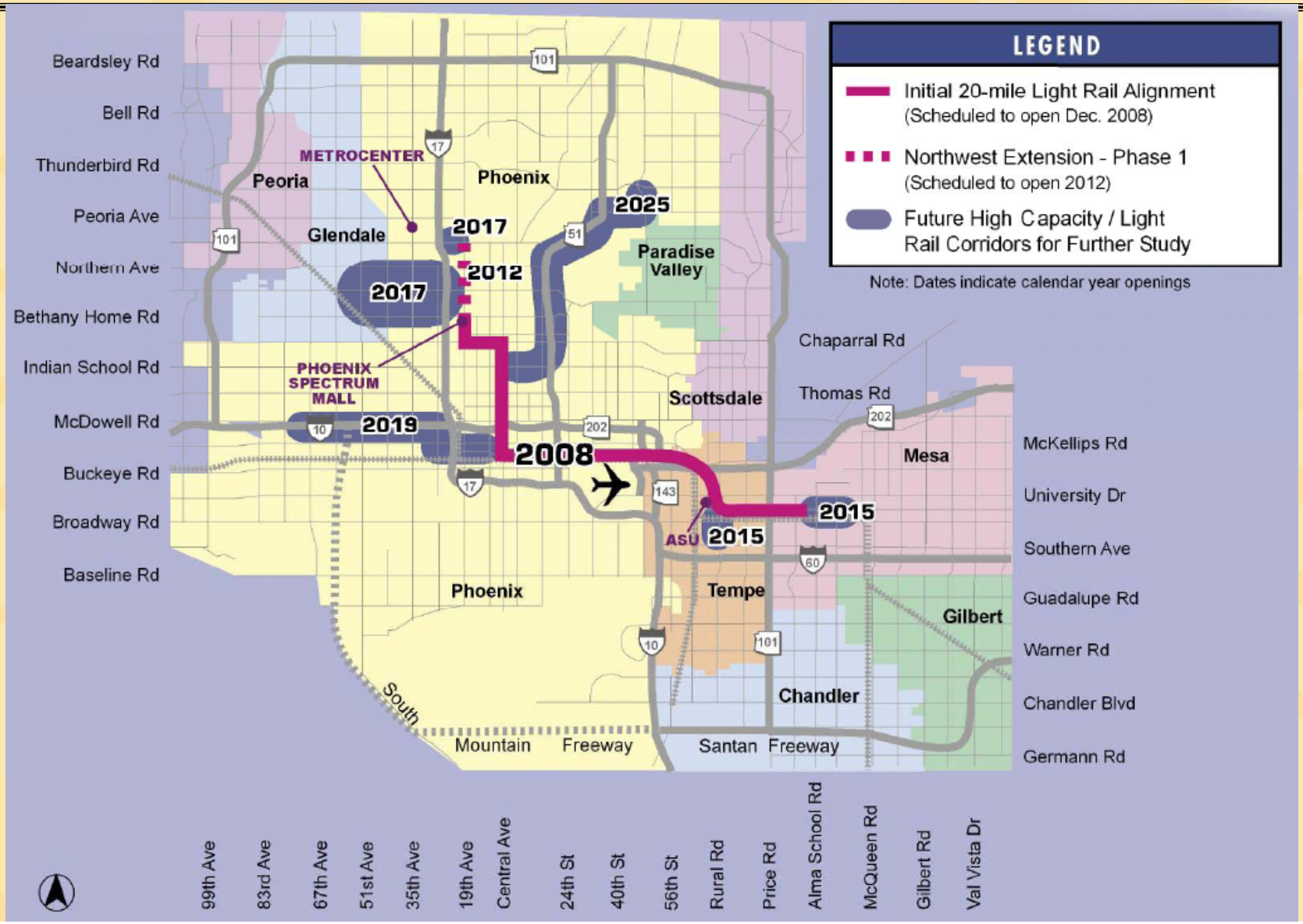
About the Phoenix Metropolitan Area

- Population of 4.28 million
  - 12th most populated metropolitan area in the country
- The City of Phoenix is the 5th largest in the U.S.
- Phoenix is the most populated capital city in the U.S.
- 8 cities in the area have 100,000+ people
  - Phoenix
  - Mesa
  - Tempe
  - Gilbert
  - Chandler
  - Peoria
  - Scottsdale
  - Glendale

Line Rail Transit

- Light Rail service began in December 2008
- Starter line ~20 miles long
- Serves West Mesa, North Tempe, and Central Phoenix
- Additional lines being planned for the future
- Important service stops
  - Arizona State University
  - Mill Avenue Shopping district
  - Sky Harbor Airport
  - Professional Sports Facilities
  - Phoenix CBD

Plan for Future Light Rail Corridors



Metropolitan Planning and Modeling Challenges

- Urban sprawl
  - Residential areas sprouting along the edges
- Heavy congestion during peak hours
  - Serious environmental and quality of life implications
- Rating Corridor Performance
- Incorporating multiple modes of transportation
  - Interaction between highway and transit networks
  - Modeling the addition/presence of a new mode
- Simulation run times in large metropolitan areas are prohibitive

Specific Challenges to the Phoenix Area

- Large regional scale
  - High run times and computational effort required
  - Provision of regional transit services
- High population of seasonal residents
- Mountain preserves and parks interspersed
- Shared borders with Native American Reservations

Project Objectives

- To implement TRANSIMS for a large scale region with a multi-modal network
- To apply TRANSIMS for operational analysis of a multi-modal corridor
- To develop documentation to aid the TRANSIMS user community
- This project aims to apply TRANSIMS as a tool to overcome two challenges:
  - Microsimulation on a large scale network
  - Microsimulation in a multi-modal environment

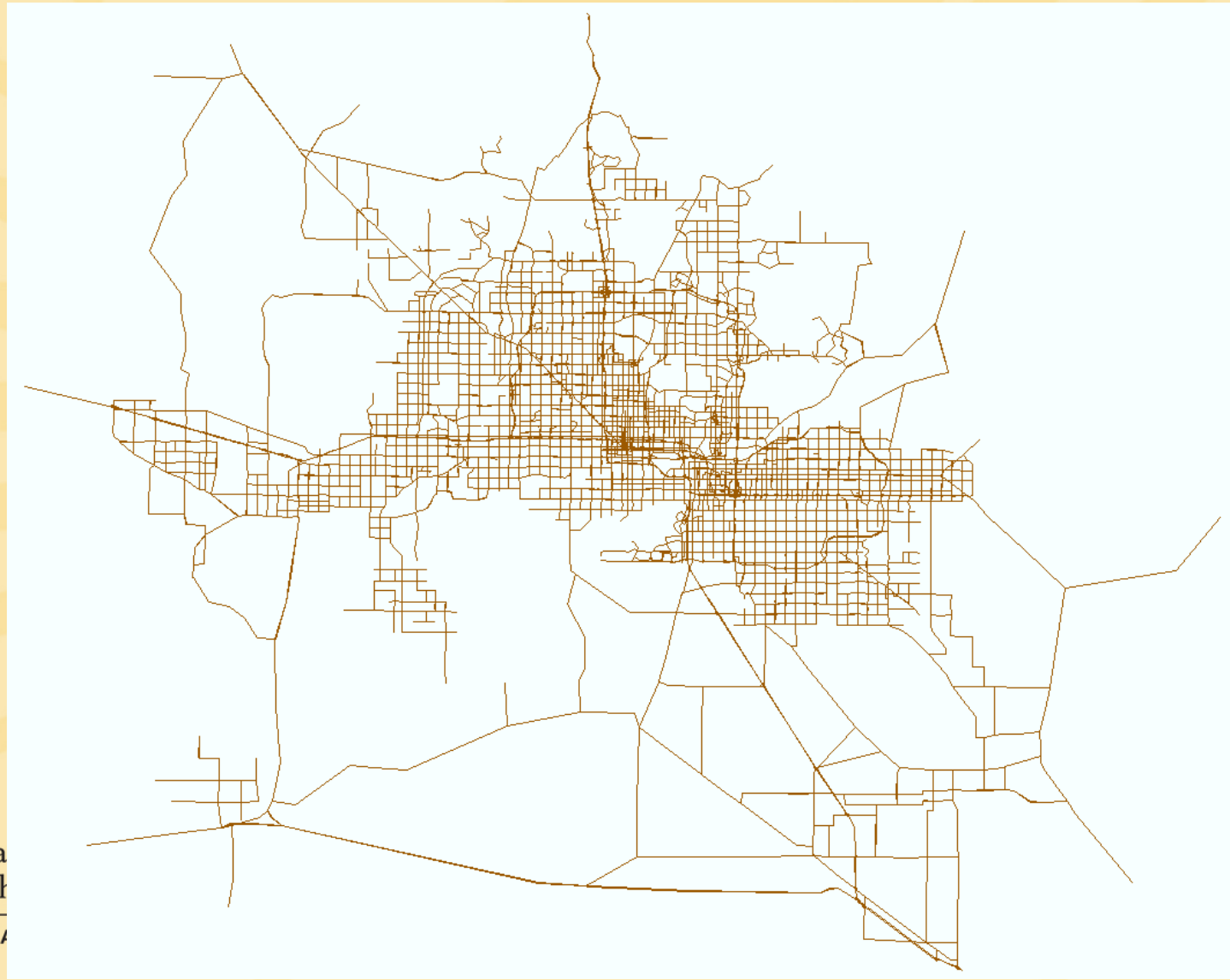
Project Phases

- Phase I: Network and Input Database Creation
  - Build a highway network
  - Build a transit network
  - Demand from Maricopa Association of Governments 4-step model
- Phase II: Calibration and Validation of Router/Microsimulator
  - Run Router/Microsimulator to convergence
  - Validate simulated traffic
  - Validate simulated transit ridership
- Phase III: Simulating Demand and Network Dynamics
  - Use validated network from phases I and II
  - Apply PopGen synthetic population generator
  - Apply TRANSIMS activity generator/scheduler

Summary of Completed Project Tasks

- Highway Network
- Transit Network
- Subarea selection and creation
- Origin-Destination matrices applied
- Creation of time-of-day distributions by purpose
- Simulation process completed
  - Router Stabilization
  - Microsimulation Stabilization
  - User Equilibrium
- Several Chapters of TRANSIMS Documentation
- Router/Microsimulator validation in progress

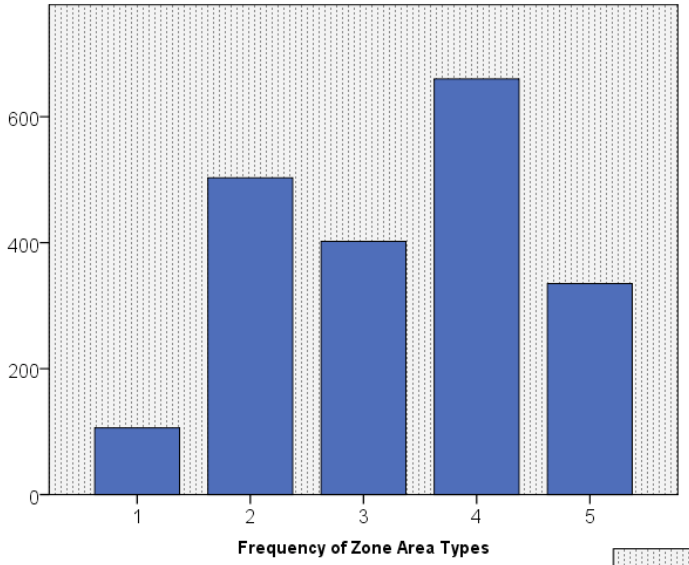
The Highway Network

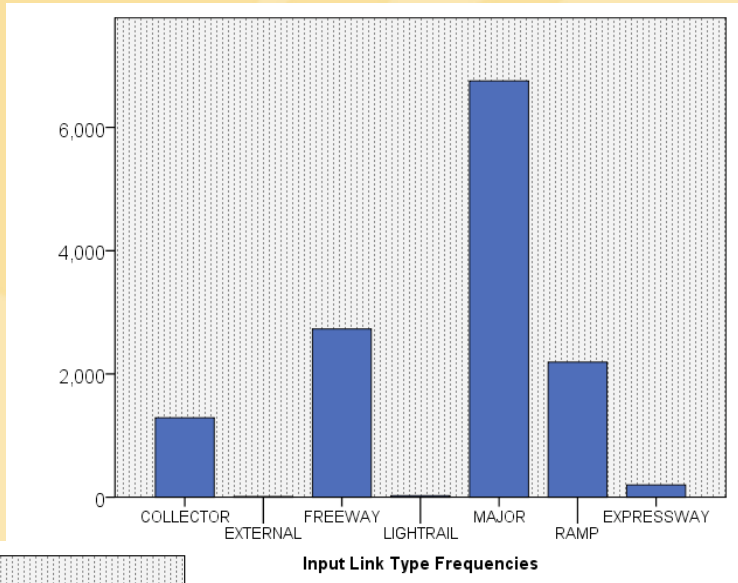


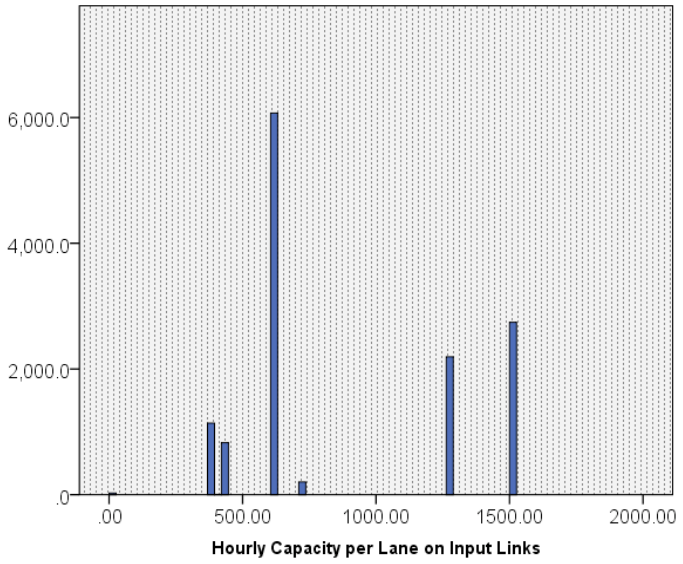
Highway Network Inputs

* All Input Data provided by Maricopa Association of Governments
- 1,995 Internal TAZs
  - Area type ranging from 1-5, 5 being most rural
- 11 External TAZs
  - All area type 5
- 10,436 Nodes
  - First 11 correspond to external zone centroids
- 13,210 Links
  - 40% of these are one-way links

Input Highway Statistics







Ira A. Fulton School of Engineering
ARIZONA STATE UNIVERSITY

Highway Network Parameters & Results

SIGNAL_WARRANT_FOR_AREA_TYPE_1	COLLECTOR, COLLECTOR
SIGNAL_WARRANT_FOR_AREA_TYPE_2	MAJOR, COLLECTOR
SIGNAL_WARRANT_FOR_AREA_TYPE_3	MAJOR, COLLECTOR
SIGNAL_WARRANT_FOR_AREA_TYPE_4	MAJOR, MAJOR
SIGNAL_WARRANT_FOR_AREA_TYPE_5	MAJOR, MAJOR
MAXIMUM_ACCESS_POINTS	3
MINIMUM_SPLIT_LENGTHS	60, 60, 60, 60,60
MINIMUM_LINK_LENGTH	10
MAXIMUM_LENGTH_TO_XY_RATIO	1.2
FIRST_EXTERNAL_ZONE_NUMBER	3000
COLLAPSE_NODES_FLAG	FALSE
ADD_UTURN_TO_DEADEND_LINKS	YES
INTERSECTION_SETBACK_DISTANCE	15

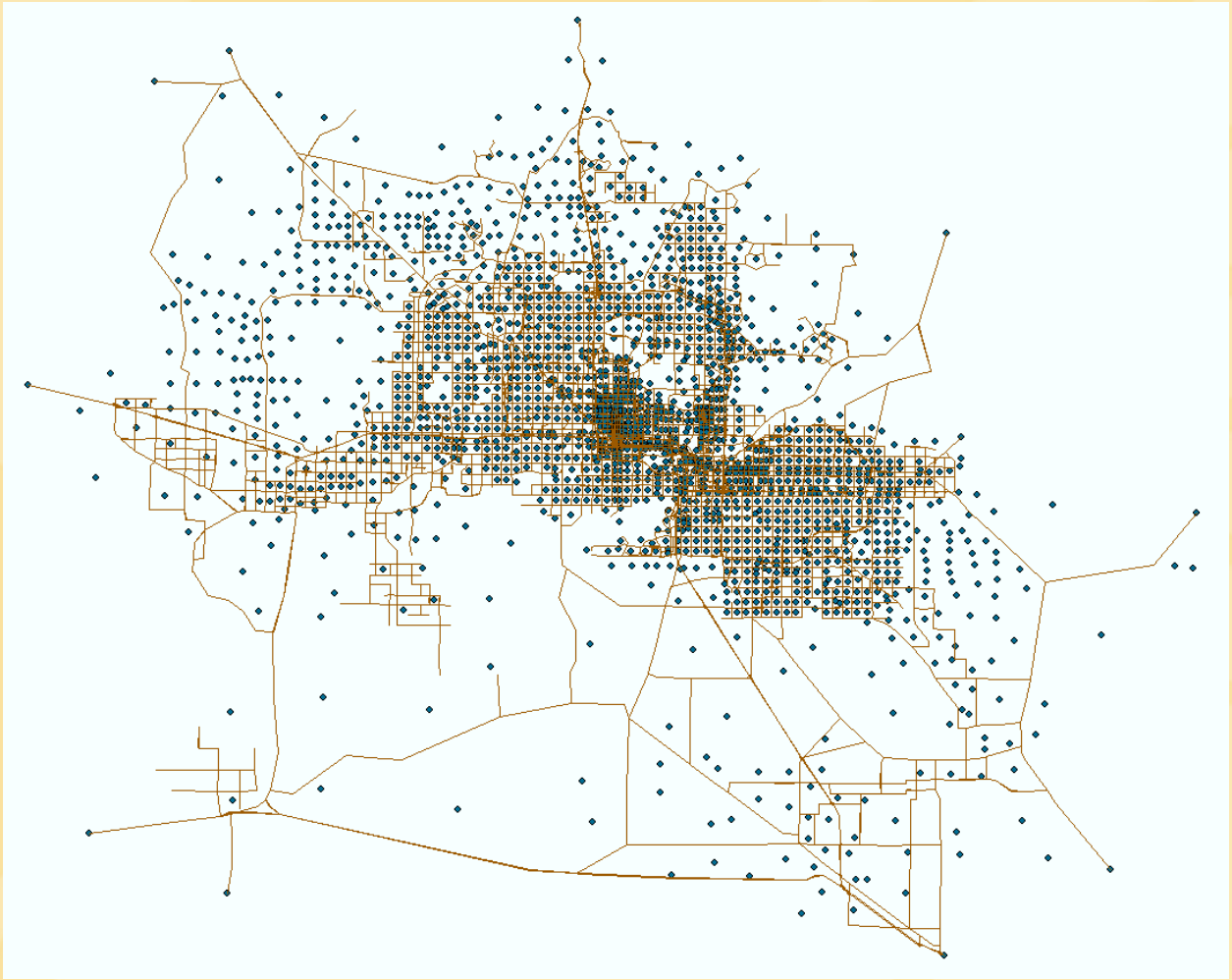
```
Number of Input Node Records = 10436
Number of Input Link Records = 13210
Number of Input Zone Records = 2006

Highest Zone Number = 3010

Number of New Node Records = 10436
Number of New Link Records = 13210
Number of New Link Shapes = 0
Number of New Shape_Records = 0
Number of New Activity Location Records = 45443
Number of New Parking Lot Records = 45443
Number of New Process Link Records = 90886
Number of New Pocket Lane Records = 0
Number of New Lane Connectivity Records = 63194
Number of New Unsignalized Node Records = 1221
Number of New Signalized Node Records = 2081

Number of External Connections = 11

Number of Short Links Increased in Length = 169

Number of Stop Signs = 691
Number of Yield Signs = 530

Number of Demand Actuated Single Ring Signals = 2081
```

Activity Location Zone Assignments

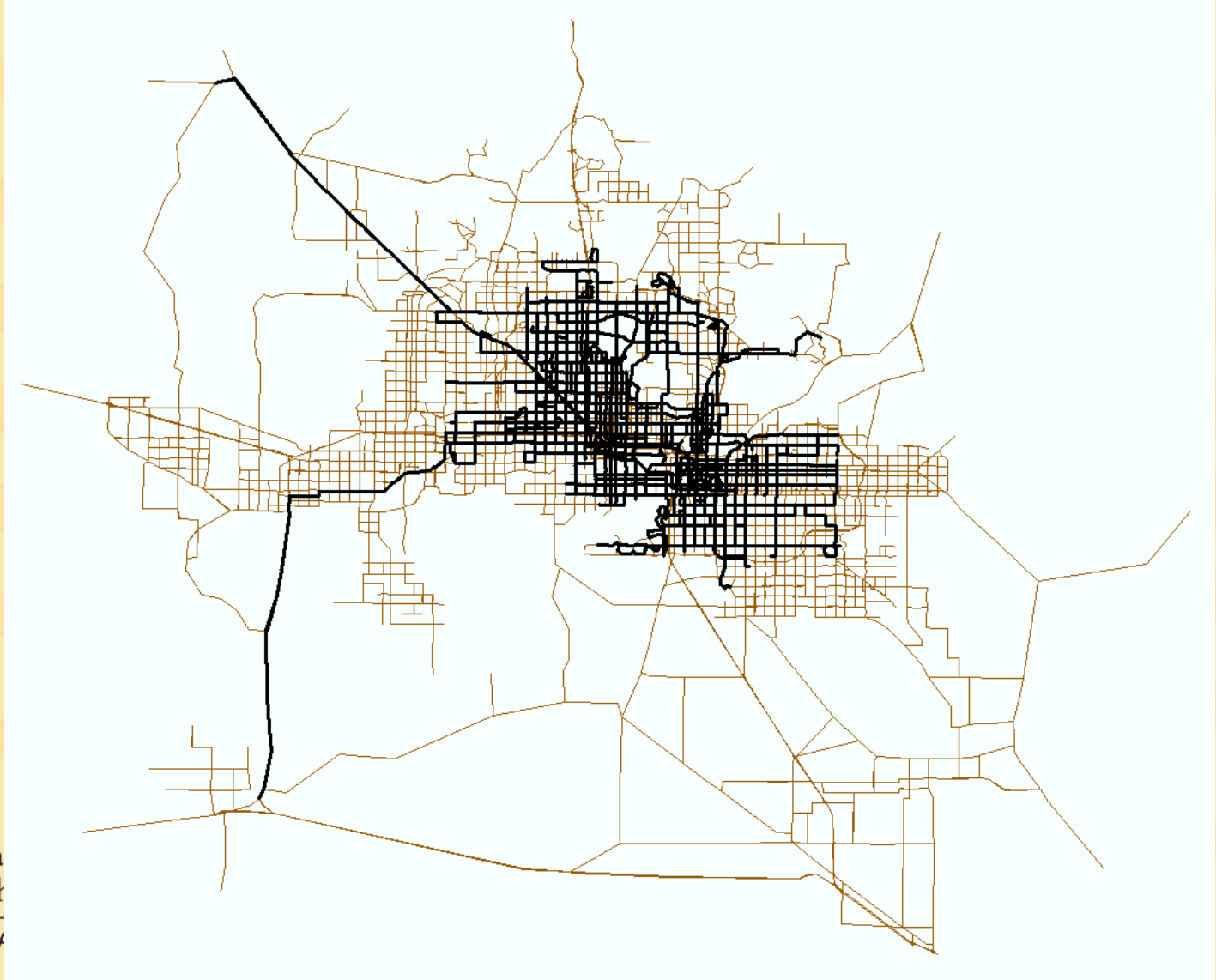
- All Activity Locations are assigned a zone
- Zone assignments based on proximity to centroid
- Areas of Phoenix where no major roadways exist
  - Mountain preserves
  - Borders with Salt River-Pima and Gila River Reservations
- Many Phoenix-area TAZ's not allocated any Activity Locations
  - Result: failure to process trips to/from those zones
- Activity Location file was enhanced manually
  - Zone allocations of some activity locations were re-assigned
- Python Script created to automate this process

Traffic Analysis Zones

Zone assignment of activity locations based on proximity to highway link



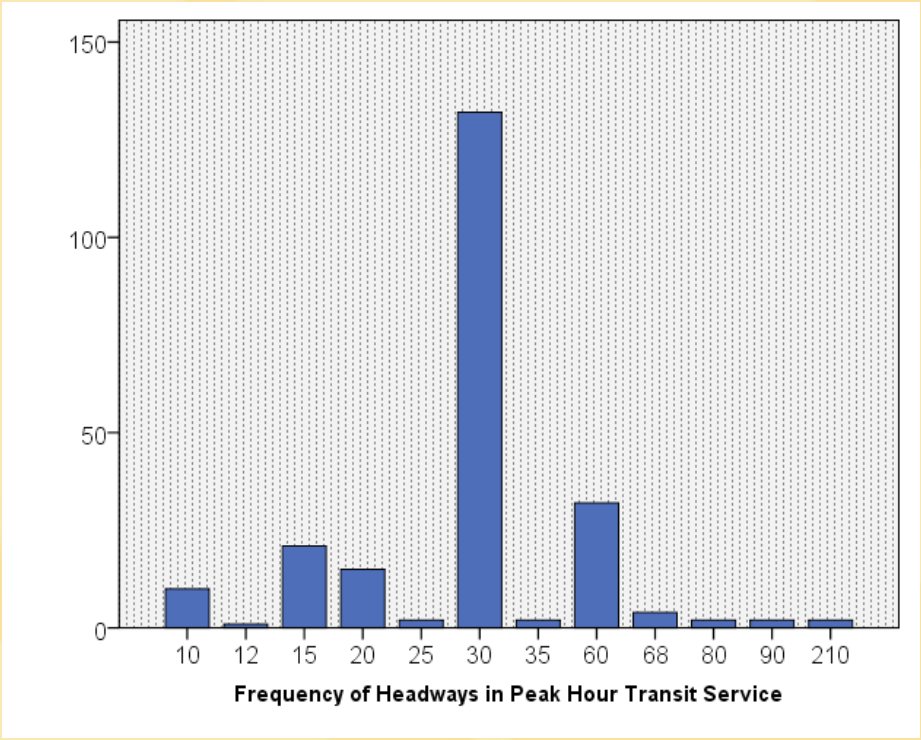
The Regional Transit Network

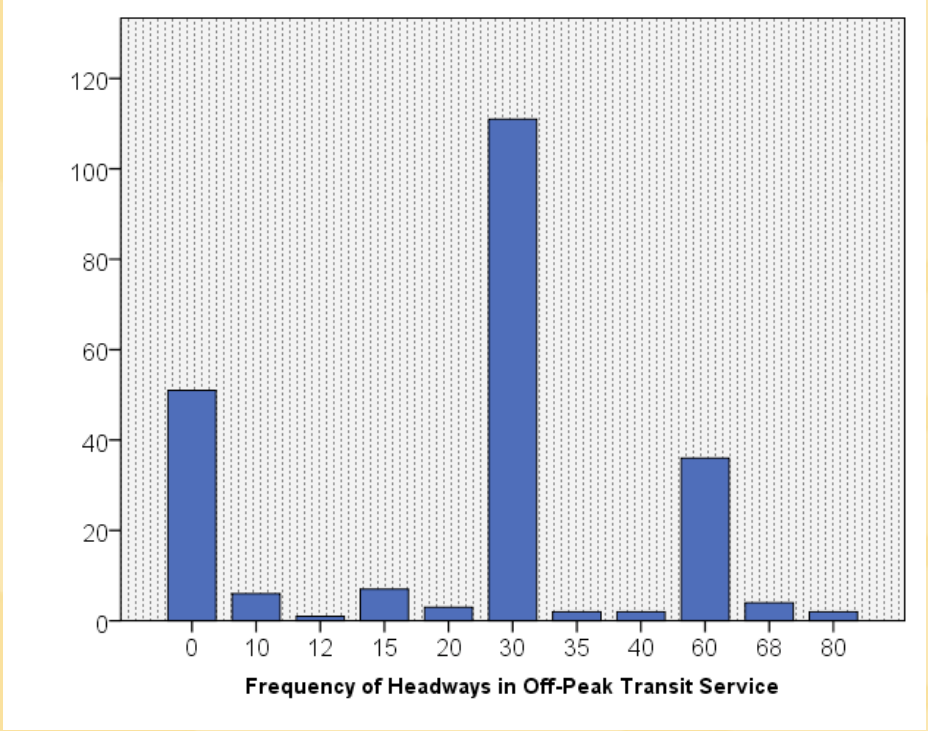


Transit Network Inputs

- 225 Routes
  - Bus, Express Bus, and Light Rail
- 7 transit time periods
  - Service runs from 4:00 am to 11:00 pm
  - AM Peak from 6:00 – 9:00 am
  - PM Peak from 3:00 – 6:00 pm
- Dwell Times
  - 20 seconds for all Bus Routes
  - 10 seconds for all Express Bus and Light Rail Routes
- "TIME" and "SPEED" between transit stops are calculated within TRANSIMS

Input Transit Statistics





Transit Network Parameters & Results

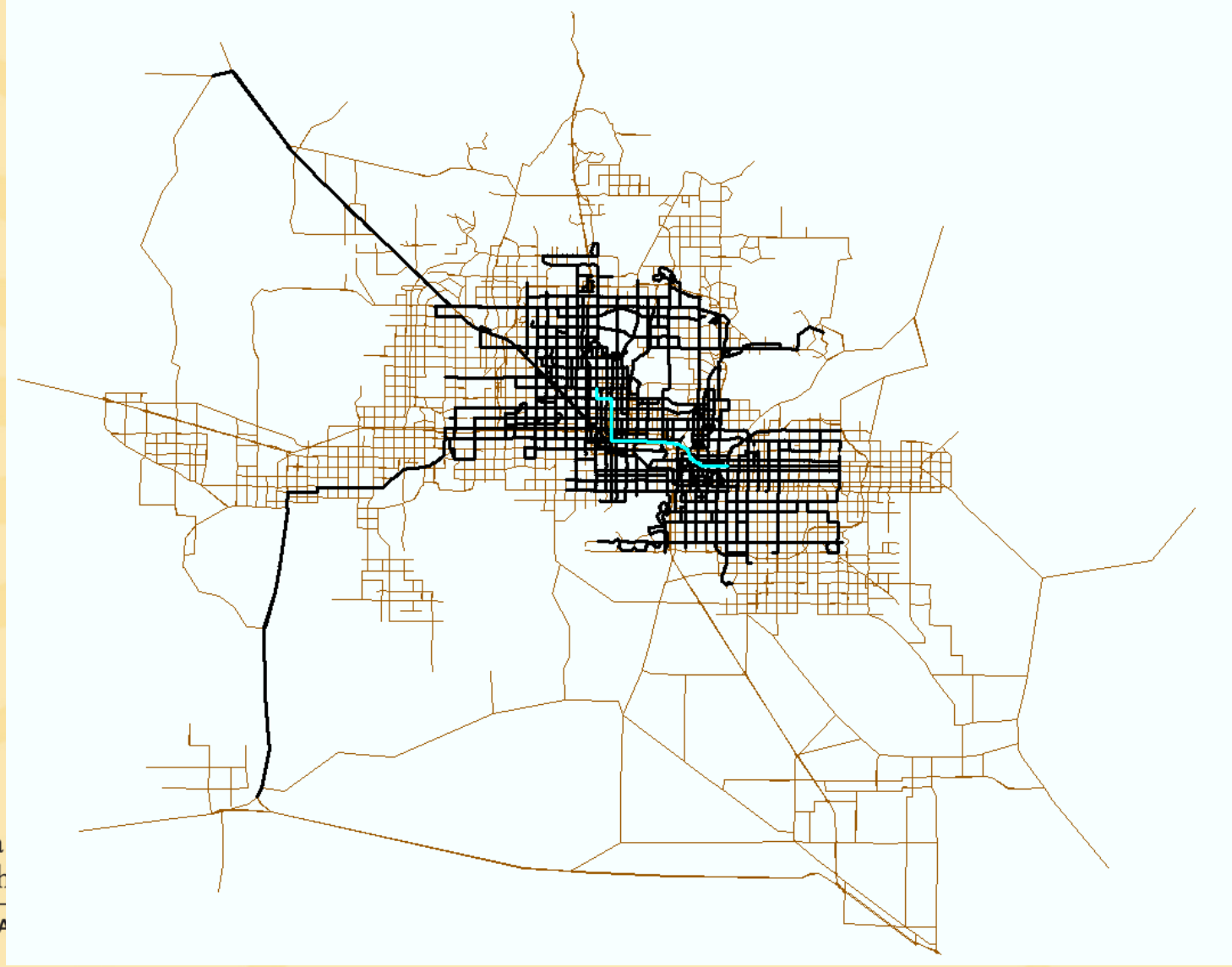
RANDOM_NUMBER_SEED	12345
MAX_WARNING_MESSAGES	10000000
TRANSIT_TIME_PERIODS	4:00, 6:00, 9:00, 15:00, 18:00, 23:00
TRANSIT_TRAVEL_TIME_FACTOR	1.0, 1.1, 1.22, 1.1, 1.25, 1.1, 1.0
MINIMUM_DWELL_TIME	5
INTERSECTION_STOP_TYPE	FARSIDE

```
Number of Activity Location Records = 53641 (7518 new)
Number of Process Link Records = 107532 (15286 new)
Number of Transit Stop Records = 7643
Number of Transit Route Records = 14055
Number of Transit Schedule Records = 433085
Number of Transit Driver Records = 12426
```

U-Turns in Bus Routes and "Must Stop" Warnings

- When bus reaches its last stop, turns around to continue in opposite direction
  - Result: Route Node file contains the same node number twice in succession
  - Error Returned: No Lane Connectivity from Node X to Node X
  - Route Node file enhanced
  - The node at the end of the line is listed only once
- Bus routes that travel on freeways
  - No bus stops on freeways in Route Node file
  - Warning Returned: Route X must stop on link Y
  - Does not seem to interfere with network creation

Current 20-Mile Light Rail Line



Light Rail Specifications

- Must identify rail in the input link file

ID	ANODE	BNODE	LENGTH	TYPE	LANES_AB	FSPD_AB	CAP_AB	LANES_BA	FSPD_BA	CAP_BA	USE
17414	11815	11816	802.405882507324	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL
17415	11815	11849	810.587176734924	LIGHTRAIL	1	8.9408	20	1	8.9408	20	LIGHTRAIL
17416	11816	11817	801.693068458557	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL
17417	11817	11818	808.782455497742	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL
17418	11818	11819	808.338805252075	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL
17419	11819	11820	809.358001762390	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL
17420	11820	11823	811.438793357849	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL
17421	11821	11831	938.315281517029	LIGHTRAIL	1	8.9408	20	1	8.9408	20	LIGHTRAIL
17422	11821	11832	797.130617294312	LIGHTRAIL	1	8.9408	20	1	8.9408	20	LIGHTRAIL
17423	11822	11851	2447.16535450745	LIGHTRAIL	1	8.9408	20	1	8.9408	20	LIGHTRAIL
17424	11822	11854	3298.34091714478	LIGHTRAIL	1	8.9408	20	1	8.9408	20	LIGHTRAIL
17425	11823	11852	861.457217033386	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL
17426	11824	11825	320.414399385452	LIGHTRAIL	1	6.7056	20	1	6.7056	20	LIGHTRAIL

- Must identify rail in the input route header file

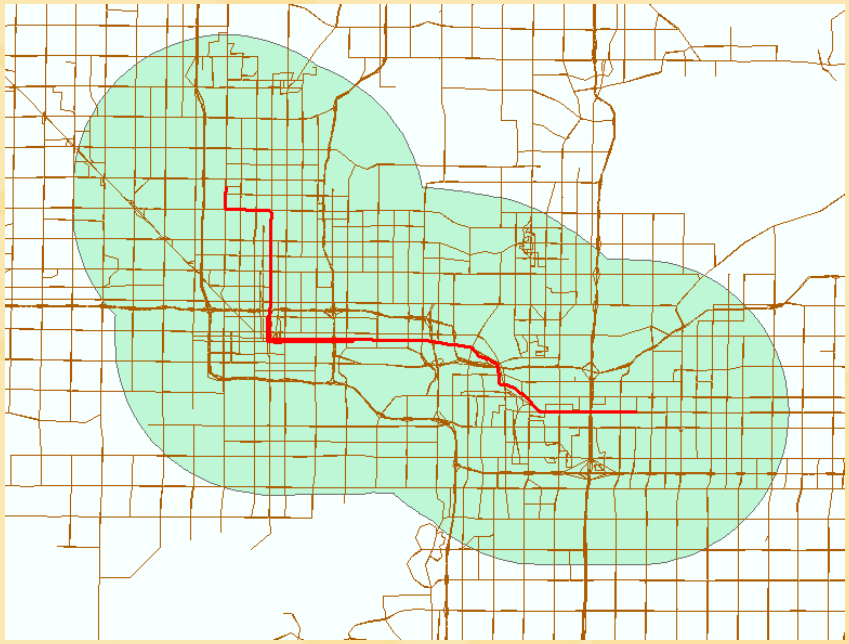
ROUTE	NAME	MODE	HEADWAY_1	HEADWAY_2	HEADWAY_3	HEADWAY_4	HEADWAY_5	HEADWAY_6	HEADWAY_7
224	LRRedE	LIGHTRAIL	0	10	10	10	10	10	0
225	LRRedW	LIGHTRAIL	0	10	10	10	10	10	0

Light Rail Subarea Creation

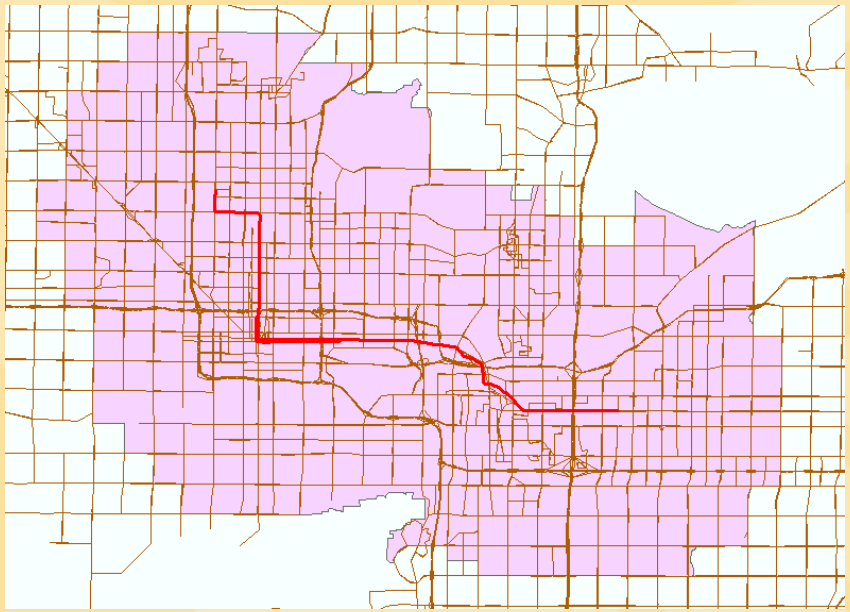
- The MAG region is a very large scale area
  - Microsimulation best done for the specific area of interest, i.e., the Light Rail Corridor
- A 5-mile buffer deemed appropriate to capture the market of the Light Rail line
- Subarea creation process:
  - Create a 5-mile buffer around the existing 20-mile Light Rail Line and its planned extensions
  - Expand the buffer to include the extents of any TAZs that lie partially within the buffer
    - This step was done to avoid trip assignment issues involving zones only partially in the subarea

Example of Expanding the Buffer

5-mile Buffer

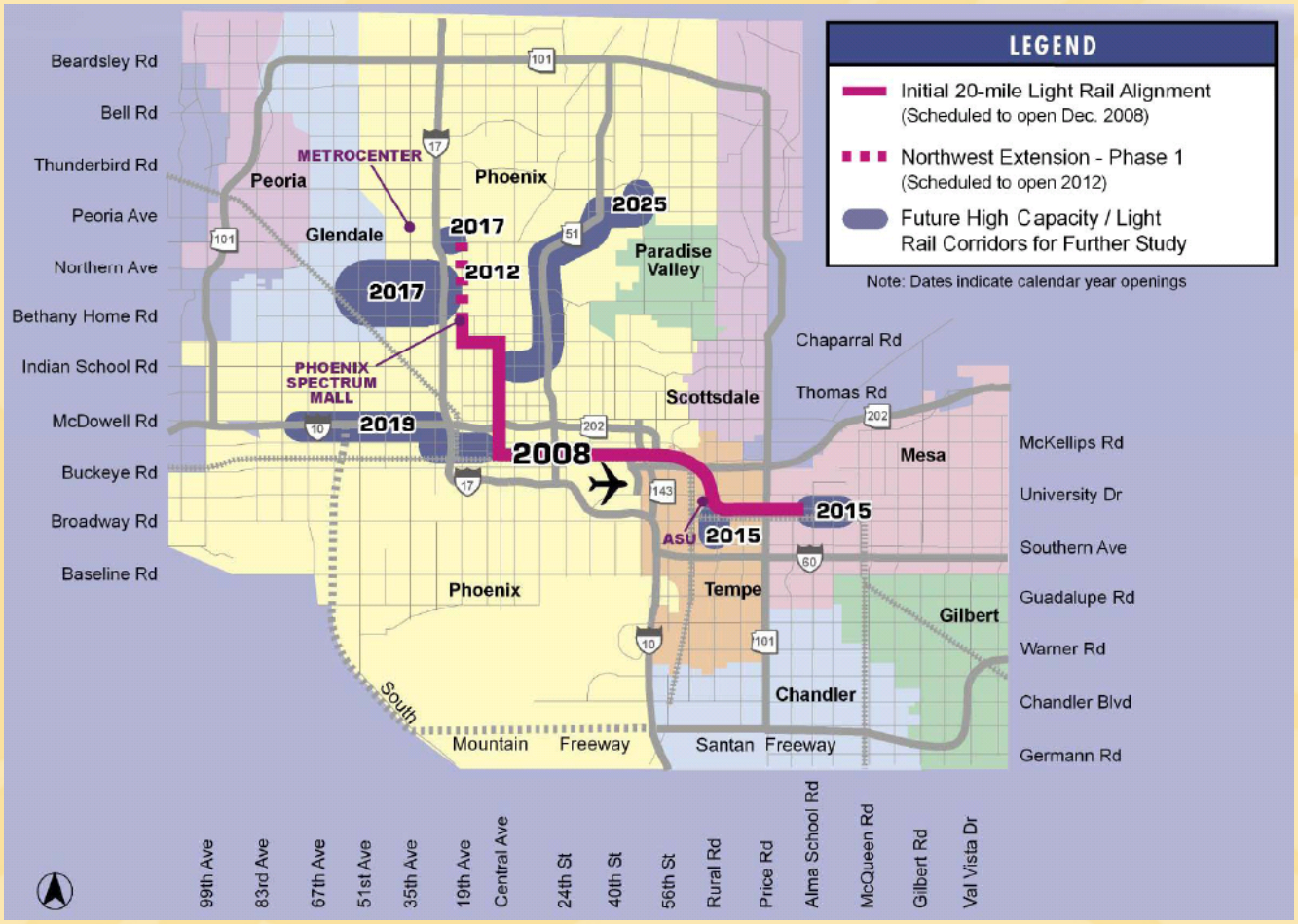


Subarea



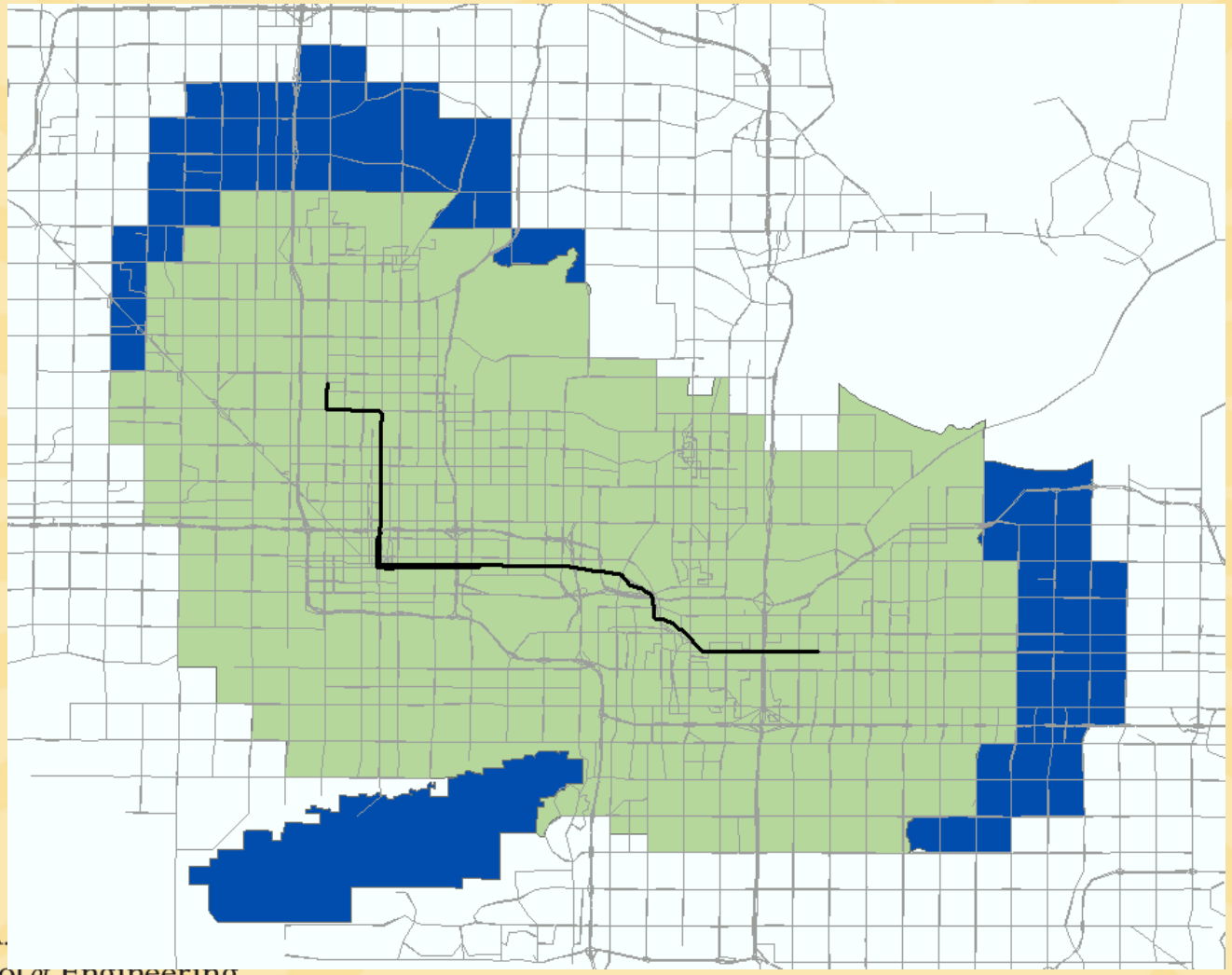
Future Planned Extensions

Northwest Extension and Mesa Extension are being considered



Ira A. Fulton School of Engineering
ARIZONA STATE UNIVERSITY

Light Rail Buffer: Existing and Future



Origin-Destination Matrices

- O-D matrices provided by MAG
  - 24 hr Drive Alone
  - 24 hr HOV
  - Local Bus Peak & Off Peak
  - Express/Rapid Bus Peak & Off Peak
  - Light Rail Peak & Off Peak
  - 24 hr Light, Medium, and Heavy Truck
- Purpose distributions created from MAG-provided data
  - ASU
  - HBU
  - HBW
  - HBO
  - NHW
  - NHO

Note: Express/Rapid Bus only included HBW trips

Origin-Destination Matrices

- Result: 26 O-D Matrices entered into TRANSIMS
  - Each has specific mode and purpose
- Matrices are zone-to-zone trip tables
- TRANSIMS does not accept fractional trips
  - Bucket Rounding was applied to each matrix to avoid loss of trips
- Results of Convert Trips
  - 15,092,164 Trips
  - 14,910,781 Vehicles
- Convert Trips Run Time = 18 minutes

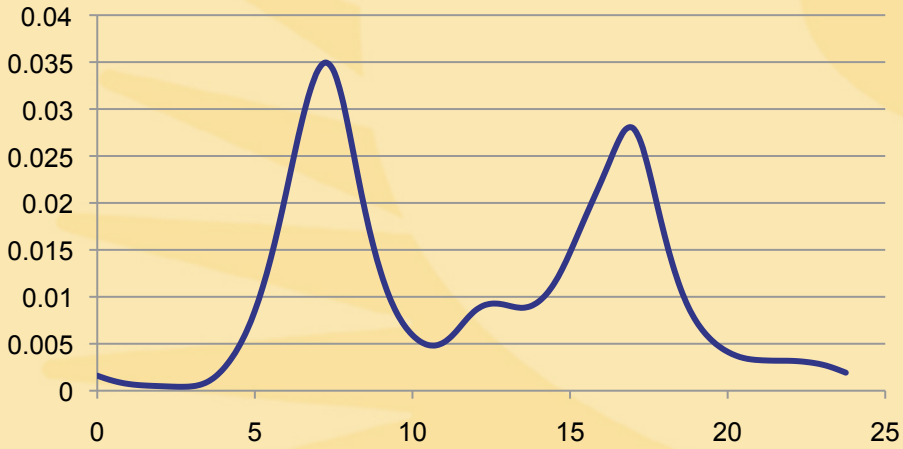
Time-of-Day Distributions

- Time-of-day distributions created from NHTS 2009 Data
- Distributions by purpose
  - NHTS trips were categorized to match MAG model trip purpose labels
- One time-of-day distribution specifically for truck trips
- Smoothing time distributions:

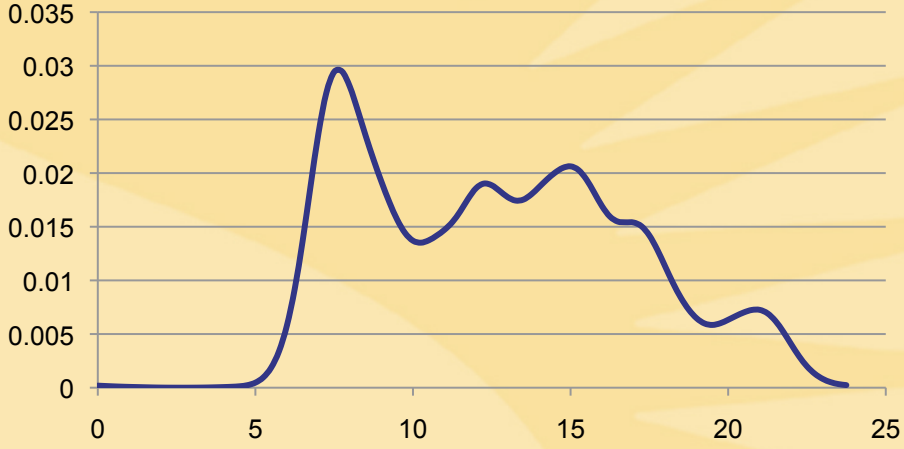
```
SMOOTH_FIELD_NUMBER      3
SMOOTH_GROUP_SIZE        3
PERCENT_MOVED_FORWARD    20
PERCENT_MOVED_BACKWARD   20
NUMBER_OF_ITERATIONS     10
CIRCULAR_GROUP_FLAG      TRUE
```

Smoothed Time Distributions

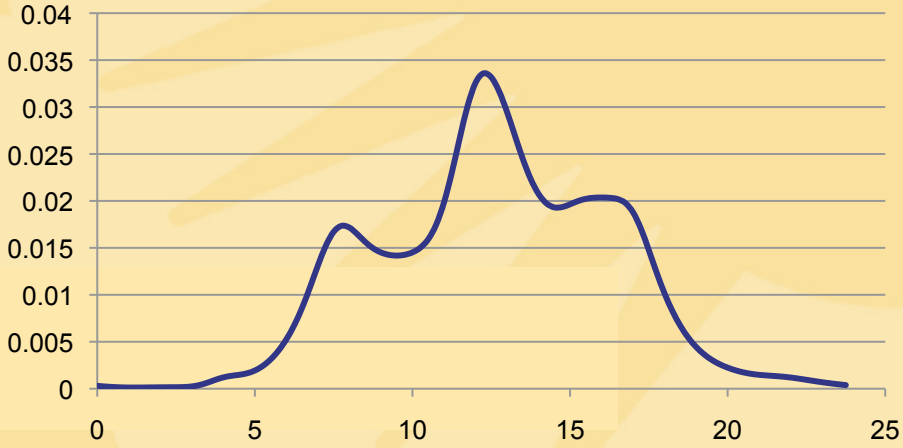
HBW Purpose Time Distribution



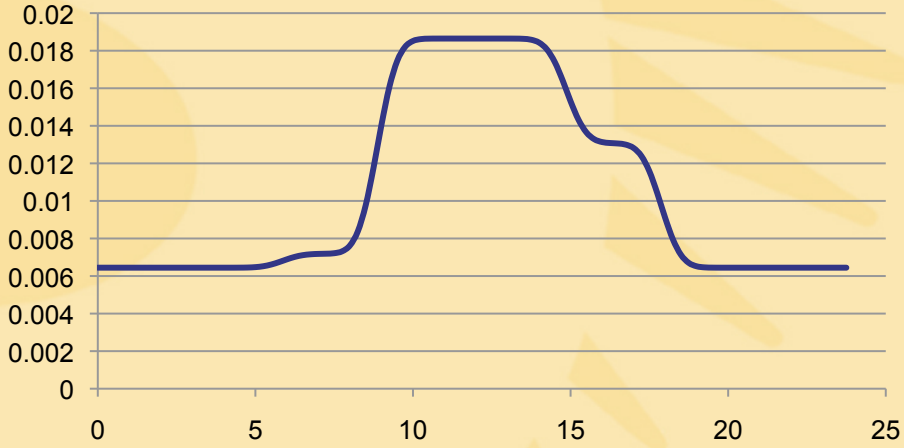
ASU Purpose Time Distribution



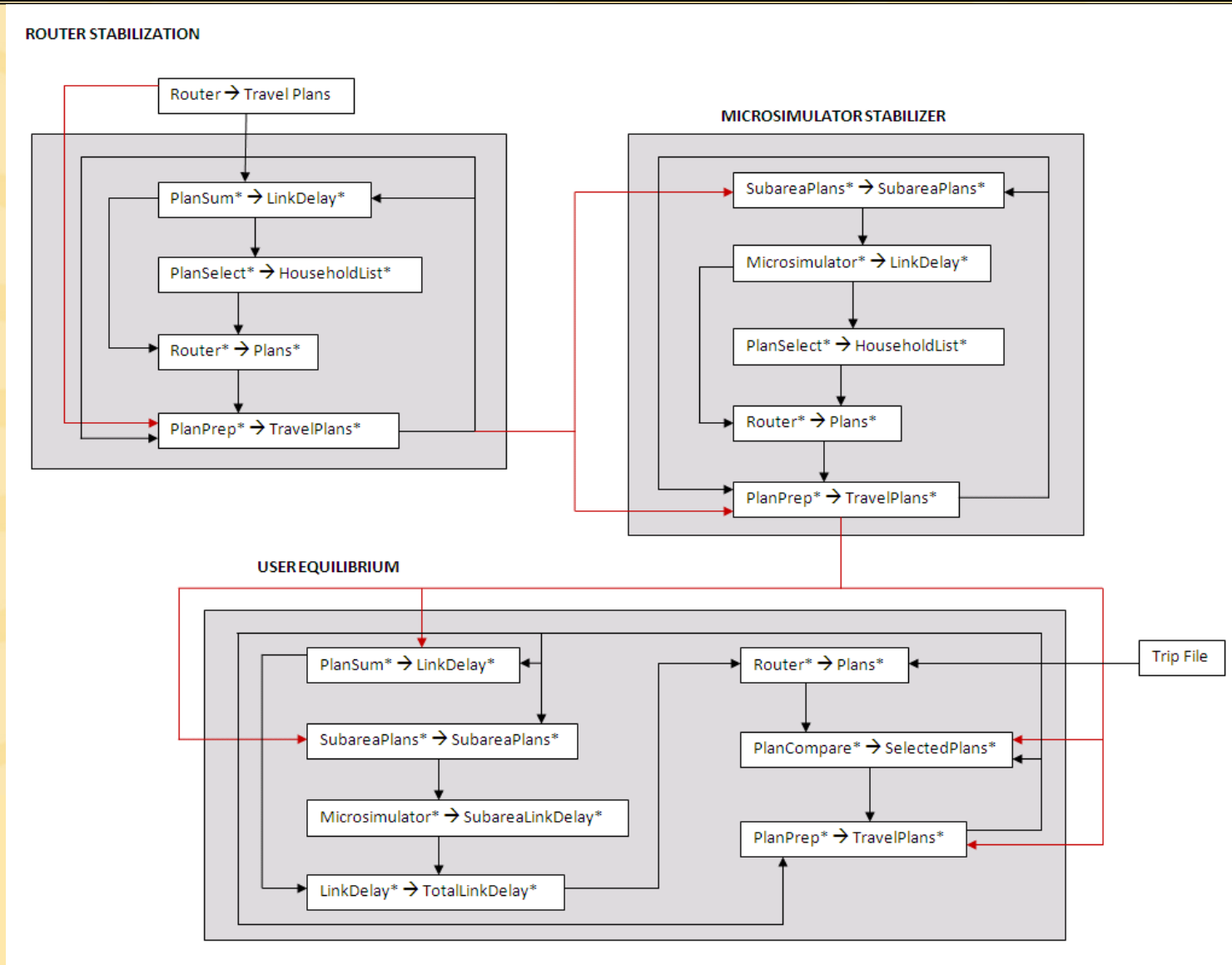
NHW Purpose Time Distribution



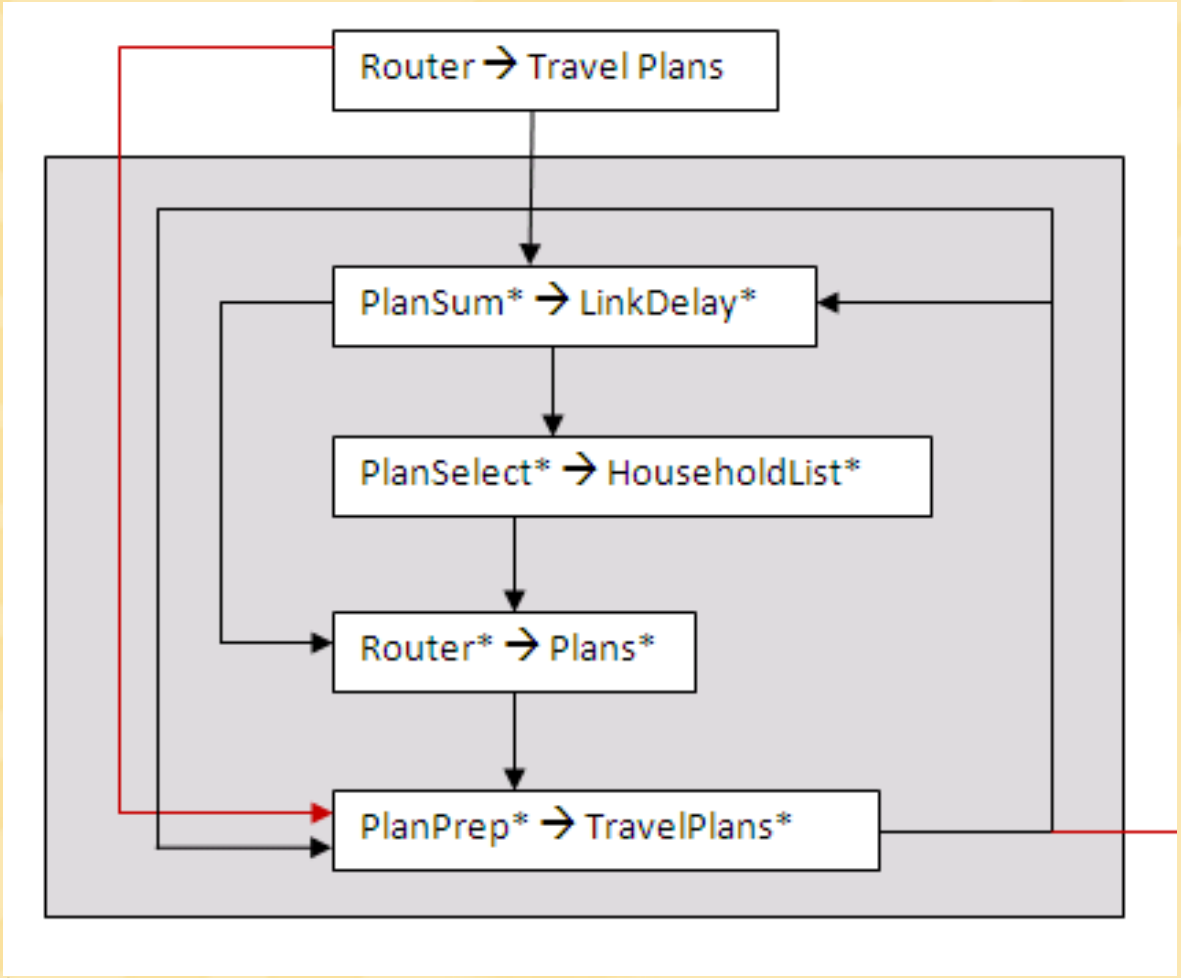
Time Distribution for Trucks



Simulation Process



Router Stabilization Process



Router Stabilization

- 15 iterations of the process are run
  - 1st Router Run: About 1,808,000 Problems
  - Problems are eliminated by 15th iteration
- Majority of Router Problems are “Time Schedule” Problems
- Initial Router Run Time = 12 Hours (single core Dell Inspiron D630 laptop)
- Entire Router Stabilization process run time = 20:55:38

Router Stabilization Parameters

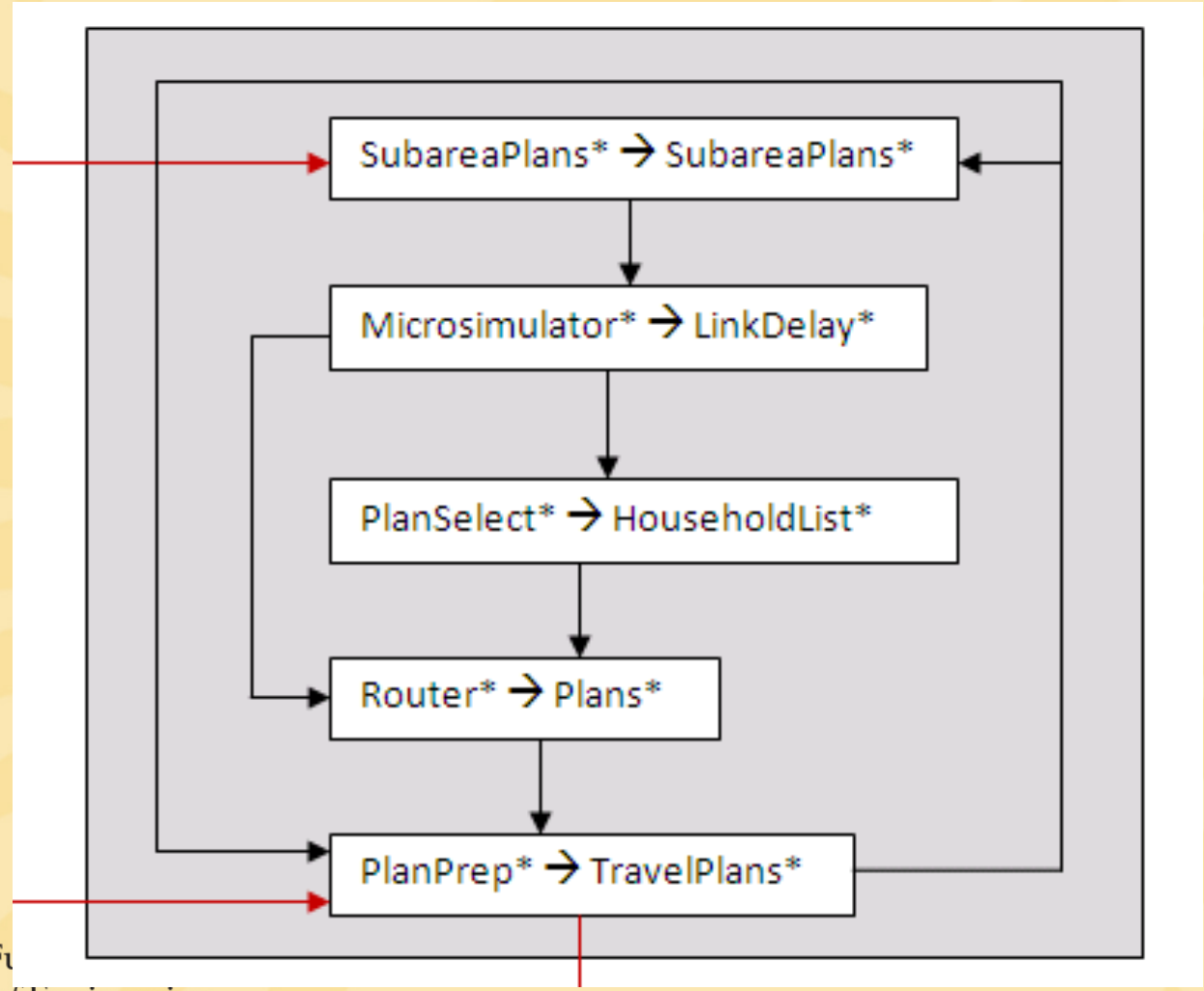
- Router

NODE_LIST_PATHS	FALSE
END_TIME_CONSTRAINT	5
PERCENT_RANDOM_IMPEDANCE	20
RANDOM_NUMBER_SEED	1234
WALK_SPEED	2
BICYCLE_SPEED	10
FIRST_WAIT_VALUE	15
TRANSFER_WAIT_VALUE	20
VEHICLE_TIME_VALUE	10
U_TURN_PENALTY	100
TRANSFER_PENALTY	200
RAIL_BIAS_FACTOR	0.8
MAX_WALK_DISTANCE	1500
MAX_BICYCLE_DISTANCE	10000
MAX_WAIT_TIME	60
MIN_WAIT_TIME	3
MAX_NUMBER_OF_TRANSFERS	4
MAX_CIRCUITY_RATIO	5
MAX_ROUTING_PROBLEMS	10000000
EQUATION_PARAMETERS_1	BPR, 0.25, 4, 1
EQUATION_PARAMETERS_5	BPR, 0.25, 2, 1

- Plan Select

PERCENT_TIME_DIFFERENCE	5
MINIMUM_TIME_DIFFERENCE	2
MAXIMUM_TIME_DIFFERENCE	30
SELECT_TIME_PERIODS	4:00..24:00
MAXIMUM_PERCENT_SELECTED	10
SELECTION_PERCENTAGE	50
RANDOM_NUMBER_SEED	1234

Microsimulation Stabilization Process



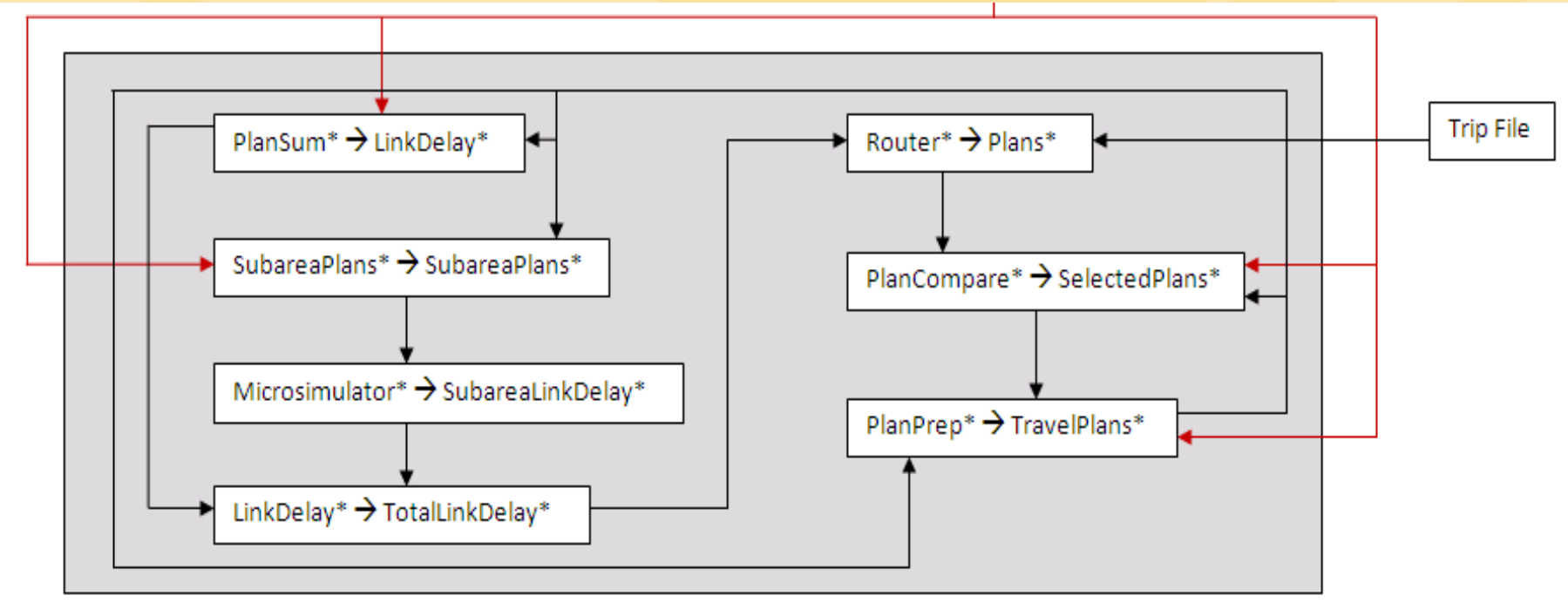
Microsimulation Stabilization

- 10 iterations of the process
- Entire Microsimulation Stabilization process run time = 6:25:04
- First Microsimulator Run returned 3,065 problems
  - Majority were departure time problems
- Subarea Plans
  - Need to ensure that the external offset length in Subarea Network is sufficient

- Microsimulator Parameters

NODE_LIST_PATHS	FALSE
CELL_SIZE	6
TIME_STEPS_PER_SECOND	1
SIMULATION_START_TIME	0:00
SIMULATION_END_TIME	24:00
SPEED_CALCULATION_METHOD	CELL-BASED
PLAN_FOLLOWING_DISTANCE	525
LOOK_AHEAD_TIME_FACTOR	1.0
LOOK_AHEAD_LANE_FACTOR	4.0
LOOK_AHEAD_DISTANCE	260
DRIVER_REACTION_TIME	0.7
RANDOM_NUMBER_SEED	0
MINIMUM_WAITING_TIME	60
MAXIMUM_WAITING_TIME	120
MAX_DEPARTURE_TIME_VARIANCE	60
MAX_ARRIVAL_TIME_VARIANCE	60

User Equilibrium Process



User Equilibrium

- Process was established similar to the White House Area Transportation Study
- 10 iterations of the process
- Entire User Equilibrium process run time = 42:37:34
- LinkDelay.exe
  - Inputs are subarea link delay and average link delay from region
  - Output is a regional average link delay

Validation in Progress

- First validation revealed problems with the network
  - All previously listed information on simulation processes could change with new network enhancements implemented recently
- Most recent validation: traffic volumes under-estimated

Summary Statistics by Volume Level

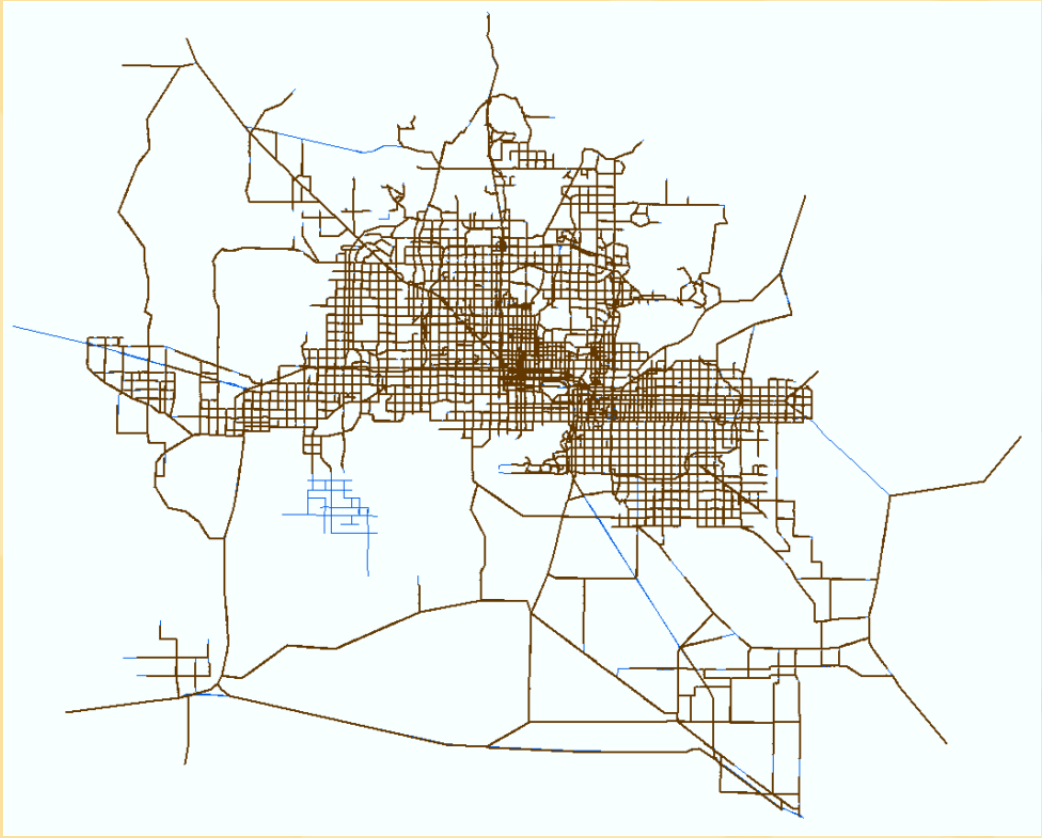
Volume Level	Num. Obs.	Volume Estimate	Volume Observed	Difference Volume	Difference %	Abs.Error Avg.	Abs.Error %	Std. Dev.	% RMSE	R Sq.	V/C Avg.	V/C Max.
10000 to 25000	22	331982	348195	-16213	-4.7	5225	33.0	4544	43.3	0.013	0.22	0.53
25000 to 50000	13	380954	515343	-134389	-26.1	16002	40.4	9053	45.9	0.275	0.20	0.38
50000 to 75000	27	886579	1690446	-803867	-47.6	30323	48.4	13921	53.1	0.051	0.22	0.54
75000 to 100000	9	341716	756630	-414914	-54.8	46102	54.8	16602	57.9	0.023	0.23	0.34
100000 to 500000	13	912031	1489860	-577829	-38.8	44448	38.8	23831	43.6	0.021	0.37	0.59
TOTAL	84	2853262	4800474	-1947212	-40.6	25410	44.5	20478	57.0	0.548	0.25	0.59

Summary Statistics by Facility Type

Facility Type	Num. Obs.	Volume Estimate	Volume Observed	Difference Volume	Difference %	Abs.Error Avg.	Abs.Error %	Std. Dev.	% RMSE	R Sq.	V/C Avg.	V/C Max.
Freeway	68	2593830	4556794	-1962964	-43.1	30337	45.3	19707	53.9	0.481	0.24	0.59
Minor Arterial	16	259432	243680	15752	6.5	4471	29.4	2849	34.5	0.065	0.34	0.53
TOTAL	84	2853262	4800474	-1947212	-40.6	25410	44.5	20478	57.0	0.548	0.25	0.59

Validation in Progress

- Just received more accurate and complete validation file from MAG
- In the meantime, checking network connectivity and making enhancements
  - Dummy trip file from Activity Location 1 to all other Activity Locations
  - Entered into router and then Arcview Plans



TRANSIMS Documentation

- Learning phase of the project suggested need for more comprehensive documentation
- Prompted the creation of “TRANSIMS for Dummies”
  - The goal: to create a one-stop document that includes all the information user will need to know about the system in informal language
  - Will facilitate quick learning and hopefully wider use of TRANSIMS
- Eventual Goal with TRANSIMS for Dummies
  - Allow user community to access via wiki and make enhancements

Project Wiki Site

- Please visit our project Wiki site:

  http://simtravel.wikispaces.asu.edu/TRANSIMS+Application+and+Deployment
- TRANSIMS for Dummies

  http://simtravel.wikispaces.asu.edu/TRANSIMS+For+Dummies
- Weekly Progress Updates on this Project

  http://simtravel.wikispaces.asu.edu/TRANSIMS+Project+Updates
- Details on other SimTRAVEL Projects
  - SimTRAVEL: *Sim*ulator of *T*ransport, *R*outes, *A*ctivities, *V*ehicles, *E*missions, and *L*and

  http://simtravel.wikispaces.asu.edu/

Where We Are Going…

- Large-scale multimodal network successfully created
  - Minor issues related to poor connectivity
- Ongoing validation checks
  - Router testing reveals approximately 12% of trips are experiencing problems
  - Accounting of HOV lane trips
- Phase 3 tasks underway
  - Synthetic population created using PopGen
  - NHTS2009 add-on survey data for MAG being processed
  - Plan to apply TRANSIMS Activity generator
  - Plan to use MAG mode choice model

Acknowledgements

- Brian Grady, Resource Systems Group, Inc.
- Terry Phemister, HDR, Inc.
- Vladimir Livshits, Sreevatsa Nippani, and Wang Zhang, Maricopa Association of Governments