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11/15/2017

MAG Behavioral Freight Model and Regional Microsimulation Model

https://connectdot.connectsolutions.com/p3dz9e4dejr/

TMIP Webinar Series

November 15, 2017

Presentation 1: MAG Behavioral Freight Model

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Prepared with assistance from:

U.S. Department of Transportation
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SHRP2 Strategic Highway Research Program 2
C20 Implementation Assistance Program Grant

Project Team:

MARICOPA ASSOCIATION of GOVERNMENTS

ADOT

PAG Pima Association of Governments

CAMBRIDGE SYSTEMATICS

RS&H

MAEC

ATRI American Transportation Research Institute

CDM Smith

IHS

infogroup

INRIX

STREETLIGHTDATA

Tioga

WALL & ASSOCIATES INC.

http://www.azmag.gov/Portals/0/Documents/MagContent/TRANS_2017-02-13_SHRP2-TRANS_2017-06-06-C20-MAG-Next-Generation-Freight-Demand-Model-Update.pdf

http://www.azmag.gov/Portals/0/Documents/TRANS_2016-06-01_Review-of-Freight-Data-Sources-for-the-Development-of-a-BehaviorBased-Freight-Model.pdf

Outline

- Project and Team Introduction
- Visualization
- Firm Synthesis
- Supply Chain Model
- Value of Advanced Behavioral Freight Models

Scope of work developed in close collaboration with FHWA and TAG:

- Emphasis on freight data and data analysis – comprehensive review of freight data sources
- Data collection, acquisitions, and analysis
- Establishments/Firm Synthesis models – innovative state-of-the-art model
- Supply Chain models – innovative state-of-the-art model
- Transport, and mode choice models
- Truck tour models – separate models for different user classes
- Operational mega-regional multimodal behavioral freight model

Innovative model components within consistent agent-based behavioral framework

Inputs	Models	Outputs	Geography	Calibration Data
MAG / PAG / AZDOT TAZ Shapefiles	**Study Area/GIS Tasks** Macro – Outside AZ – State Level Meso – Inside AZ – RAZ or MPA Level	Macro shape file Meso shape file TAZ shape file		
CBP Data for U.S. (2012 data available in June 2014) *(County level for AZ, State level for non-AZ)* Correspondence (lookup) NAICS6 – SCTG *(Industry to Commodity lookup table)* BEA's Input-Output Make and Use Tables *(Make – what commodity is produced by an industry?)* *(Use – who uses certain commodities?)*	**Firm Synthesis Model** Computes number of firms by NAICS6, SCTG, Size Disaggregates firms from County to Meso Zones using Employer Determines Supplier (Shipper) Firms Determines Buyer (Consumer) Firms	List of Supplier (Make) Firms List of Buyer (Use) Firms	Meso Zone Meso Zone	MPO/State SED data *(TAZ level data, InfoUSA, etc.)*
BEA's Input-Output Make and Use Tables *(Make-Use Table – percent of commodity used by industry)* ORNL Networks for Distance Skims	**Supplier Selection Model** Links Buyers with Suppliers Uses Size of Firm, Distance, Industry-Commodity Lookups	Supplier (Shipper) Linked with Buyer (Receiver/Buyer)	Meso Zone	Reasonableness checks
FAF 4.1 *(Annual Tons by Commodity at BEA Level)* *BEA's Input-Output Make and Use Tables* *(Make-Use Table – percent of commodity used by industry)*	**Apportionment of Commodity Flows** Disaggregates Commodity Flows among Supplier-Buyer Pairs Based on Buyer Firm Size and Tons of Goods Consumed	Annual Tons Traded between Supplier and Buyer	Meso Zone	TRANSEARCH Data Existing Truck Model
Highway and Rail Networks Distance and Time Skims Location of IMX Facilities (in AZ and outside AZ) Shipping Cost Data	**Transport and Logistics Path Choice Model** Generates Skims for Highway, Rail, Water, and Air Ben-Akiva/De Jong's Transport and Path Choice Model Generates Most Optimal Path (given costs, times, distances, location of IMXs, supplier-buyer combinations)	Selected Path and Shipment Size for Each Supplier-Buyer Combination	Meso Zone	FAF3 (or FAF4) paths TRANSEARCH Data
Commercial Vehicle Establishment Surveys SED Data Location of IMX Facilities (in AZ and outside AZ)	**Truck Type of Vehicle Choice Model** Two types of Trucks – Medium and Heavy – will be estimated Binary Logit Choice Model Key Variables – Commodity, Origin Industry, Destination Industry, Employment, FTL/LTL, Direct versus IMX	Number of Medium and Heavy Trucks	Meso Zone	DMV Data VIUS Data Existing Truck Model Expanded Truck GPS Data
ATRI GPS Data for Heavy Trucks StreetLight GPS Data for Medium and Light Trucks SED Data Model Skims –Times, Distances	**Tour-Based Truck Model** Estimates Number of Stops, Tour Completes, Stop Purpose, Location, and TOD Choice Series of MNL Models (very similar to MAG's Existing Truck Tour Model for Heavy Trucks)	Medium and Heavy Truck Tours, Truck Trips, and TOD Distributions	MAG TAZ	DMV Data VIUS Data Existing Truck Model Expanded Truck GPS Data

Rail | Pipeline | Air

Trucks

Medium Trucks | Heavy Trucks

Innovative data and large data collections and data purchases

Firm Synthesizer –

- NETS data

Supply Chain Model –

- FAF4.1
- TRANSEARCH
- BEA Make and Use Tables
- Economic Census Data 2007 (CFS 2007)
- Economic Census Data 2012 (CFS 2012 microdata for AZ)
- Sun Corridor IMPLAN data

Mode and Path Choice Model –

- Economic Census Data 2012 (CFS 2012 microdata for AZ)

Tour-based Model –

- ATRI (Heavy trucks)
- StreetLight (Medium and Light trucks)

Utilization of the 2016 commercial vehicles survey

From pilot study and freight model to fully integrated mega-regional transportation forecasting system

- Advancement of stop identification algorithms in truck GPS data by incorporating land use and other criteria
- Diversification of tour and trip by metropolitan area (MAG, PAG)
- Light truck data collections and corresponding updates to the model
- Full integration of the freight model with the regional transportation forecasting models, including the activity-based model and the four-step model
- Possible future integration with regional economic models

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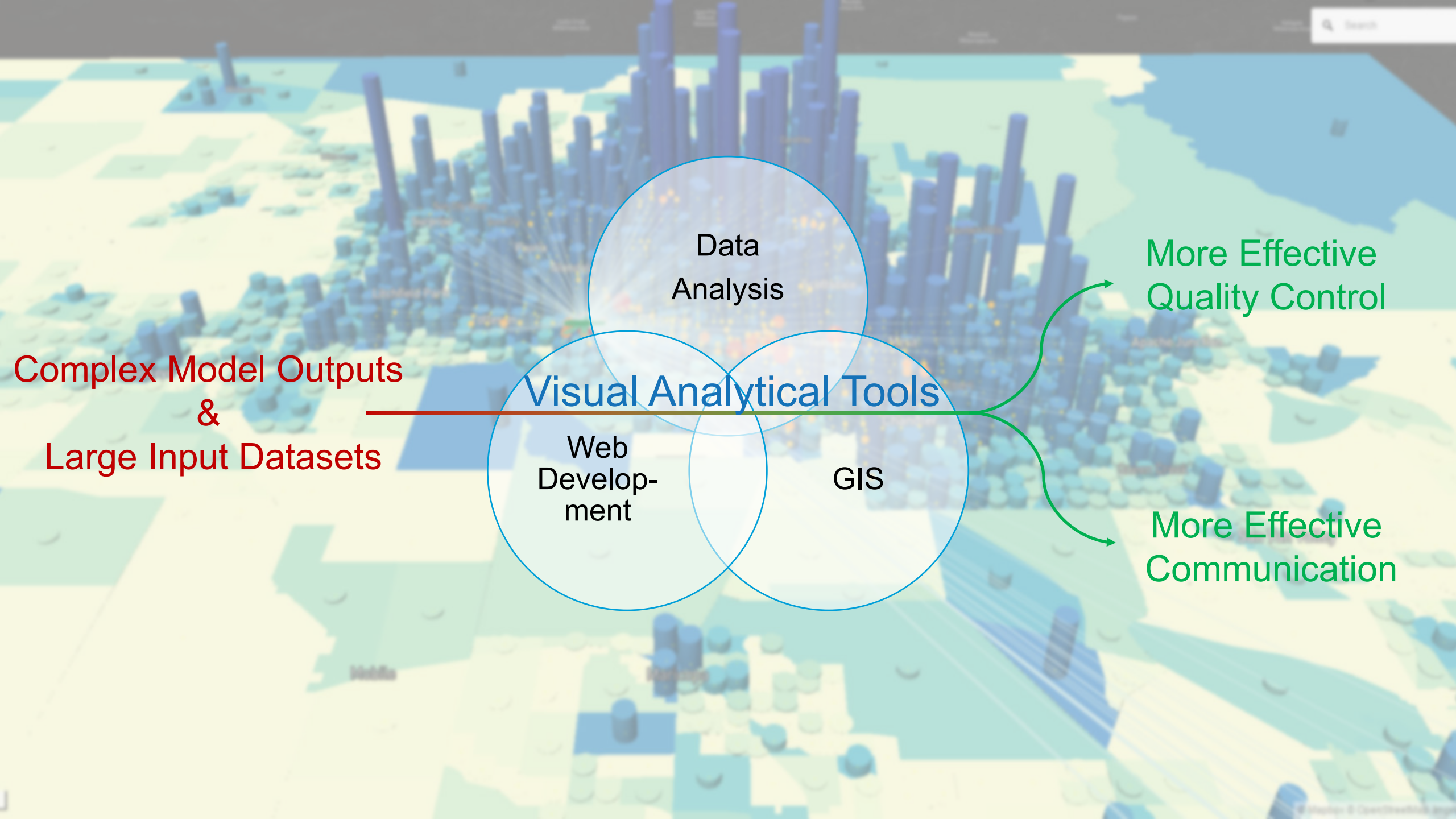

Complex Model Outputs
&
Large Input Datasets
Data
Analysis
Web
Develop-
ment
GIS
Visual Analytical Tools
More Effective
Quality Control
More Effective
Communication

Visualization Demo

- Clip1 – MAG Freight Model.mp4

Firm Synthesis Model

Synthesized Firms (Buyers and Sellers)

Supply Chain Model

Firm-level Commodity Flow

For truck mode

Truck Tour Model

Truck Tours

Number of simulated employment per TAZ

Firm Synthesis Model

Synthesized Firms (Buyers and Sellers)

Supply Chain Model

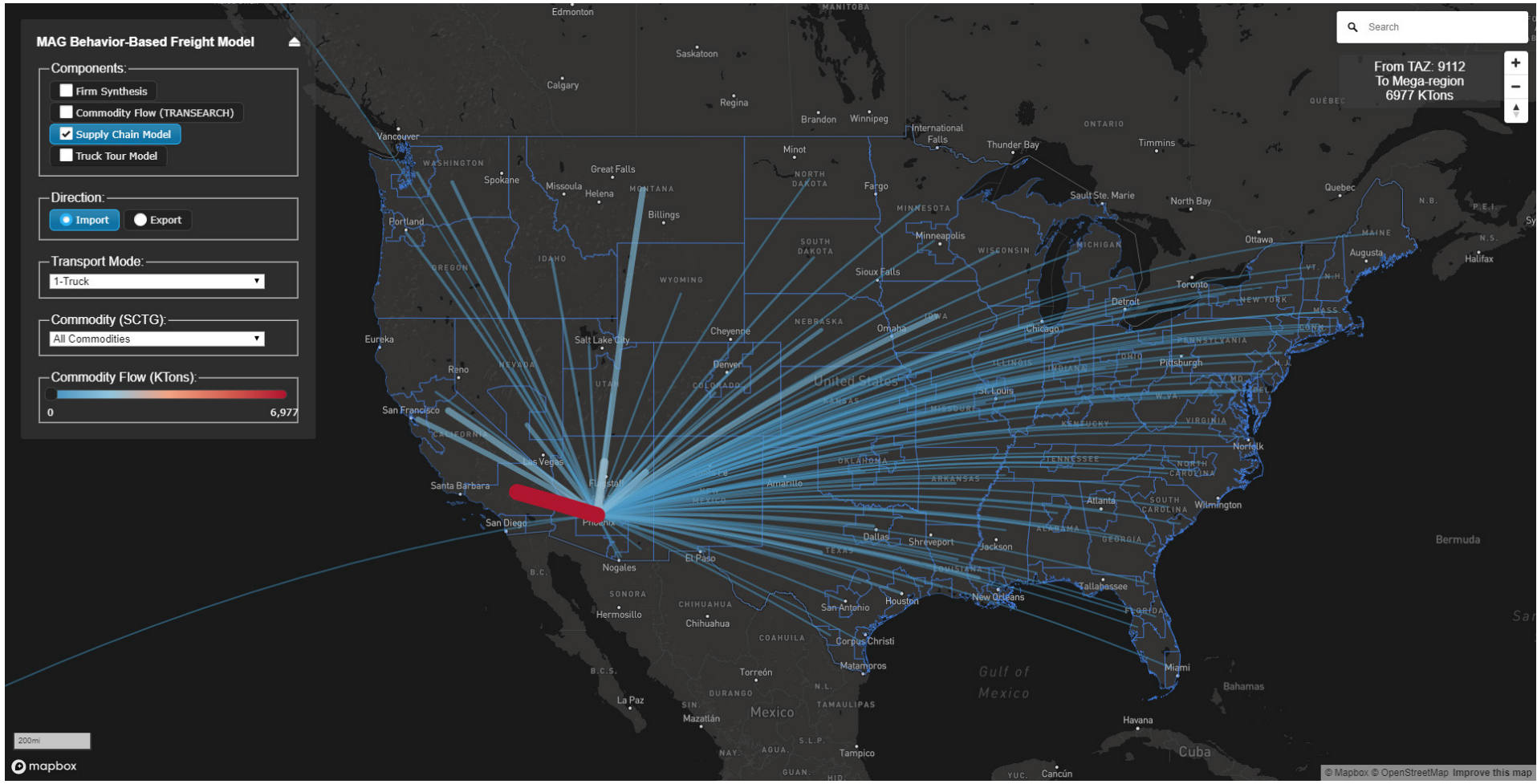
Firm-level Commodity Flow

For truck mode

Truck Tour Model

Truck Tours

Commodity Flow by Type of Goods and Mode



Firm Synthesis Model

Synthesized Firms (Buyers and Sellers)

Supply Chain Model

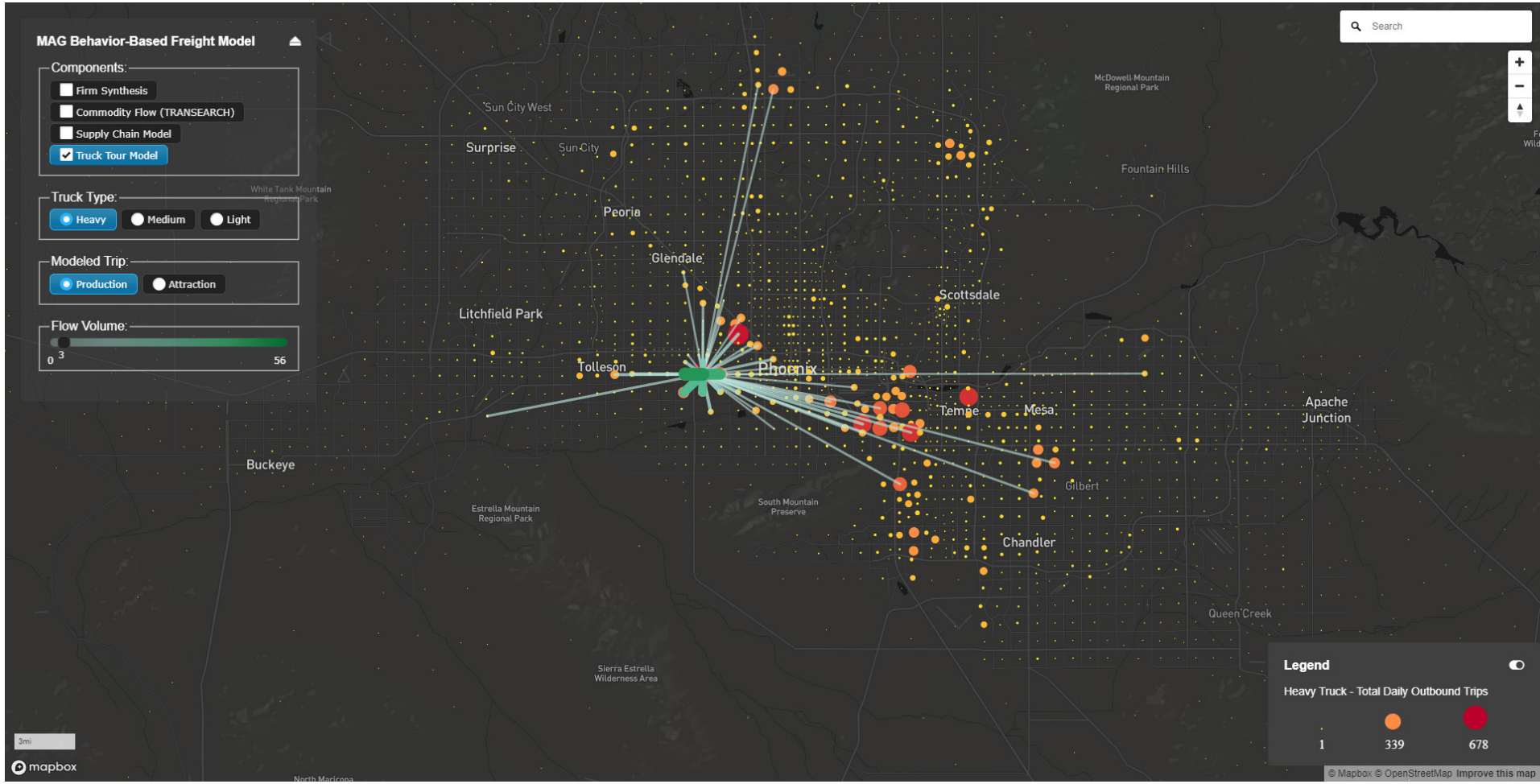
Firm-level Commodity Flow

For truck mode

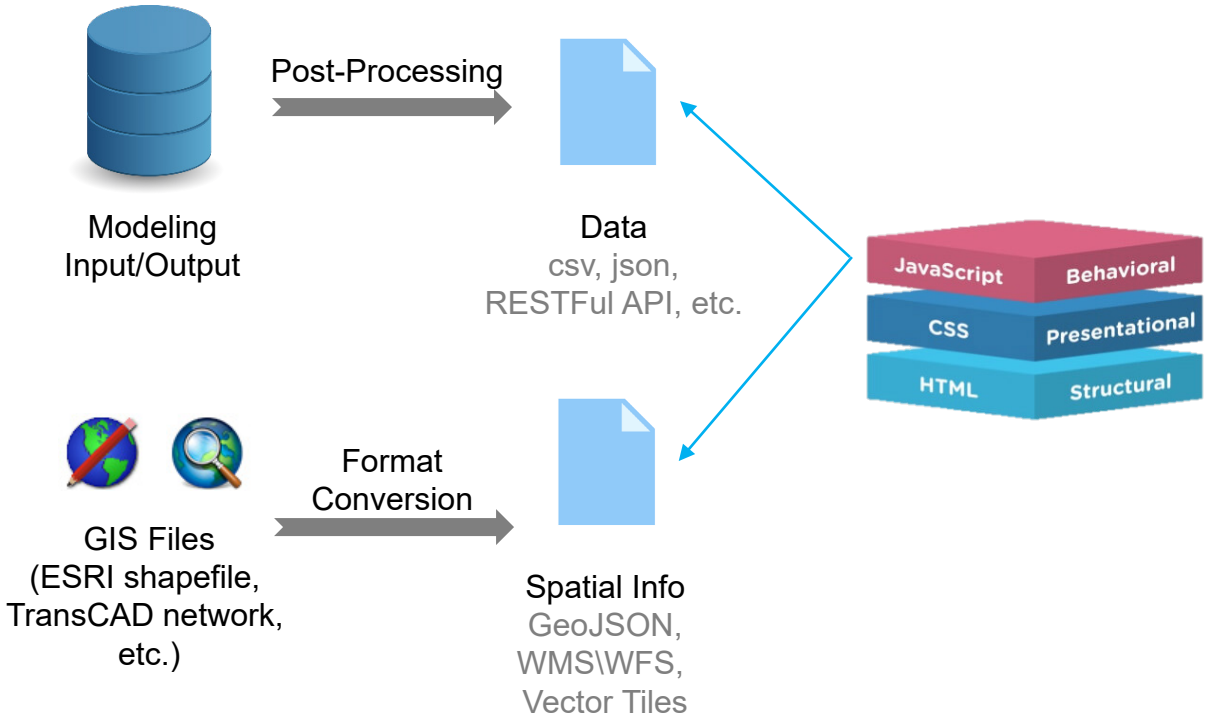
Truck Tour Model

Truck Tours

Trucks Flow Interactive Desire Line by Truck Type



Behind the Scene



Mapbox GL JS
https://www.mapbox.com/mapbox-gl-js/api/

Leaflet:
http://leafletjs.com/

For more info, please refer to Chapter 11 of the final report: http://www.azmag.gov/Portals/0/Documents/MagContent/TRANS_2017-02-13_SHRP2-TRANS_2017-06-06-C20-MAG-Next-Generation-Freight-Demand-Model-Update.pdf

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- Project and Team Introduction
- Visualization
- **Firm Synthesis**
- Supply Chain Model
- Value of Advanced Behavioral Freight Models

Firm Synthesis

Population Evolution Model

- Emigration / Immigration
- Aging / Mortality / Fertility
- Household formation / dissolution / child leaving
- Education/ Occupation / Wages

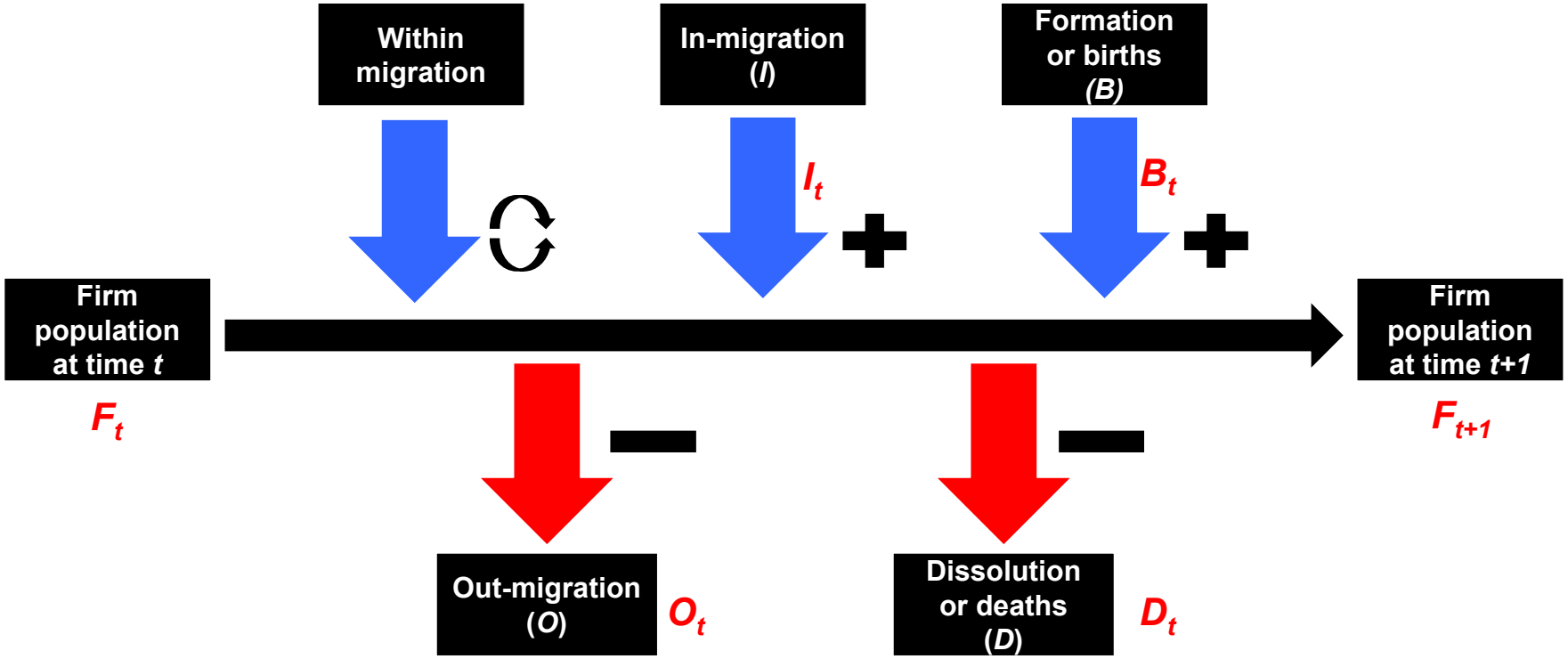
Firms Evolution Model

- Firm conception
- Firm migration
- Firm death
- Firm growth – Change in employment

Evolution of Firm Population

Accurately describes evolution of firm population in space and time

- $[F_{t+1} = F_t + B_t - D_t + I_t - O_t]$



Factors at Play in Major Events

Firm internal

- Employment size
- Sales
- Age
- Standalone/headquarters

Agglomeration economies

- Localization – number of employees within same industry
- Urbanization – number of employees from other types.

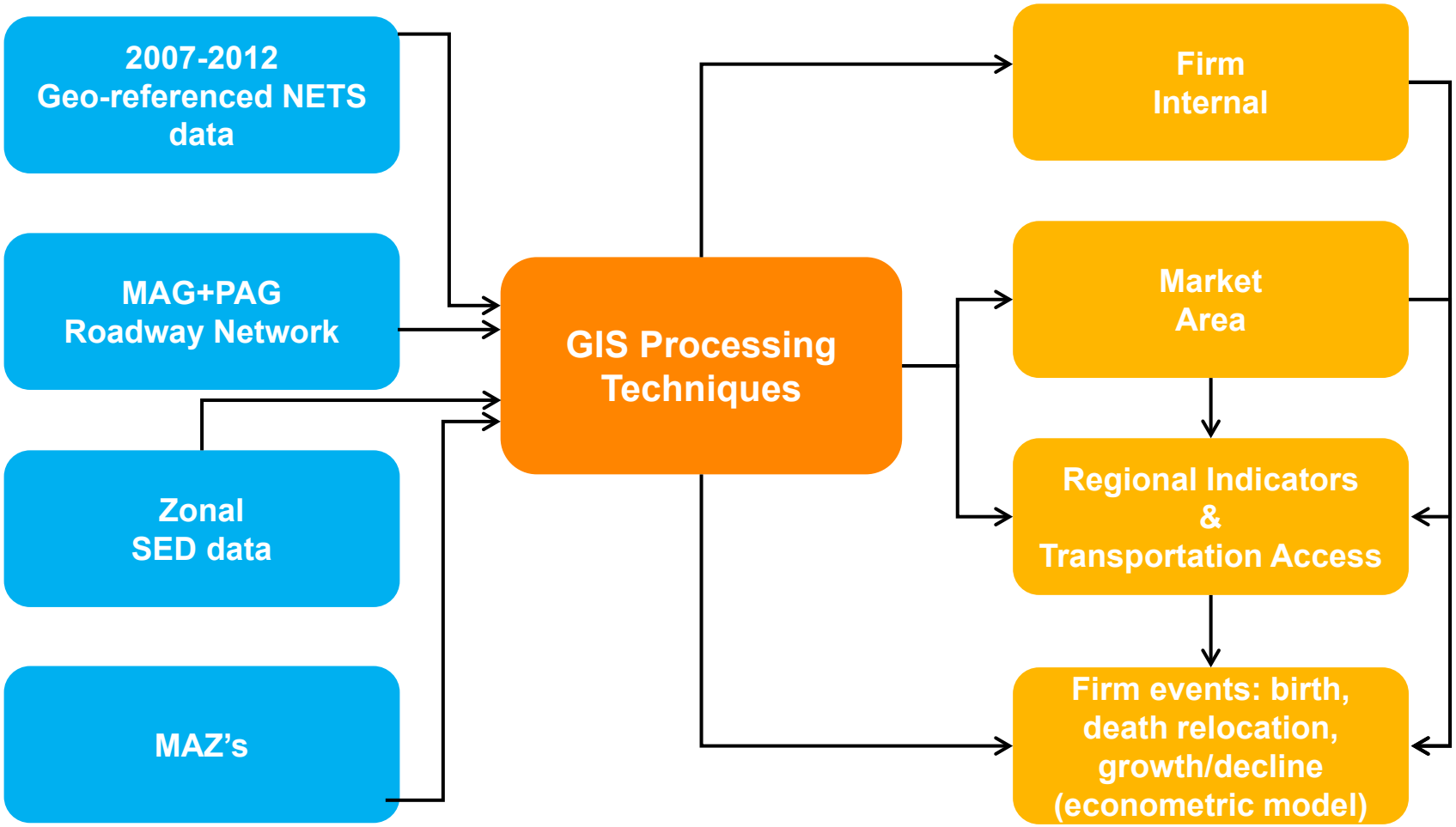
Market Area

- Population
- Average household income
- Student enrollment by school and university

Regional indicators and transport access

- Miles of roadway by facility type (e.g. freeway, arterial and minor roads).
- Flags for major hubs in the region (e.g. ASU, U *of* A and Sky Harbor Airport).

Data Processing



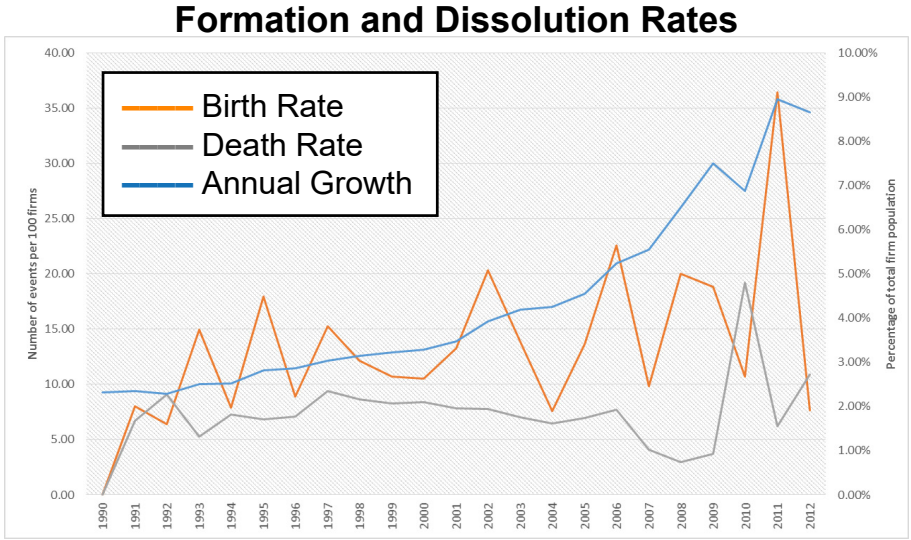
Evolution of Firm Population

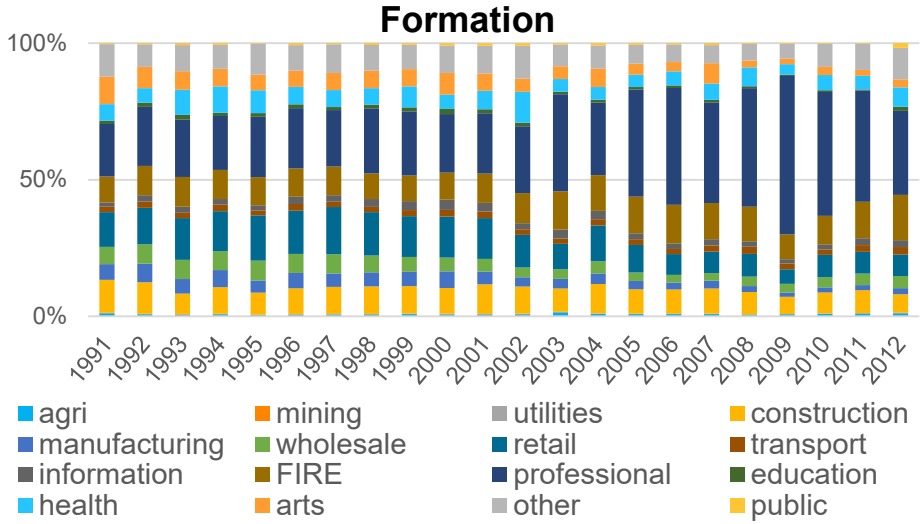
NETS Database 1990 to 2011

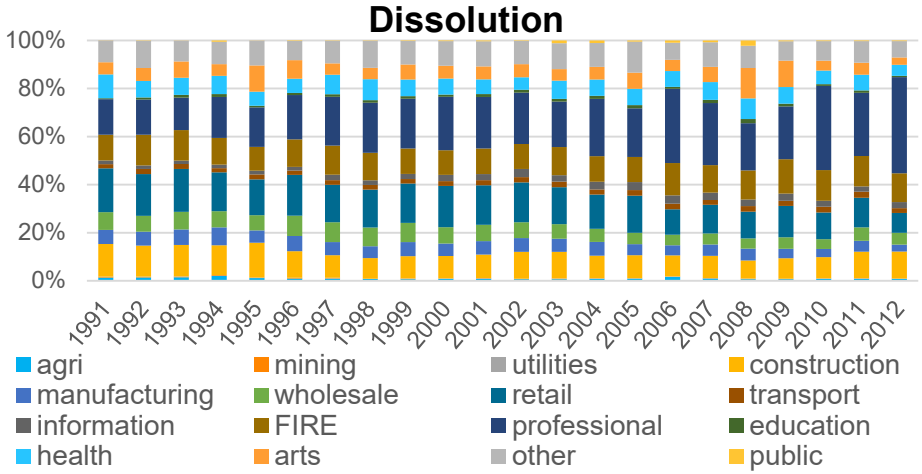
B – D + I – O + S = F

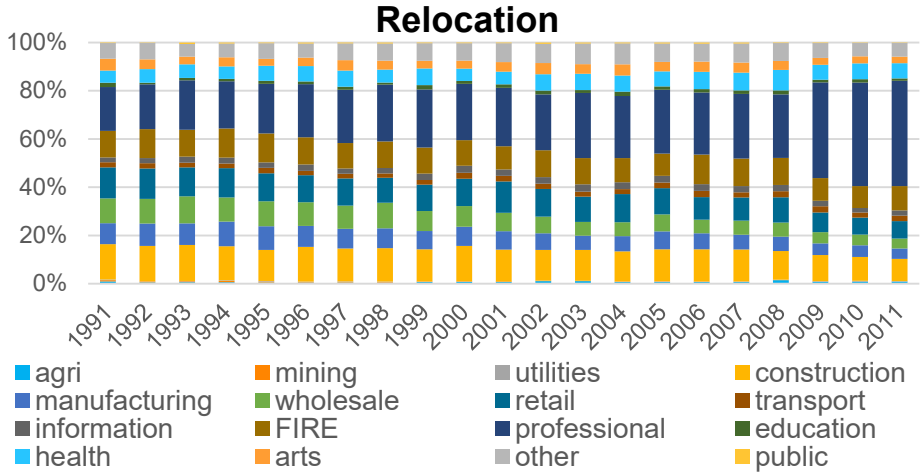
Year	Births (B)	Deaths (D)	Move-in (I)	Move-out (O)	Survivors (S)	Total (F)
1990	0	0	0	0	130,884	130,884
1991	10,488	8,800	285	164	130,884	132,693
1992	8,531	12,076	207	116	132,693	129,239
1993	19,346	6,796	294	156	129,239	141,927
1994	11,196	10,338	333	139	141,927	142,979
1995	25,669	9,800	293	119	142,979	159,022
1996	14,134	11,234	289	149	159,022	162,062
1997	24,705	15,231	229	143	162,062	171,622
1998	20,836	14,846	204	176	171,622	177,640
1999	19,072	14,718	283	144	177,640	182,133
2000	19,103	15,319	454	210	182,133	186,161
2001	24,712	14,598	755	349	186,161	196,681
2002	39,978	15,327	763	360	196,681	221,735
2003	30,618	15,531	1,108	466	221,735	237,464
2004	18,047	15,337	1,405	616	237,464	240,963
2005	32,943	16,762	1,102	441	240,963	257,805
2006	58,158	19,806	879	485	257,805	296,551
2007	29,239	12,156	779	465	296,551	313,948
2008	62,895	9,262	1,232	676	313,948	368,137
2009	69,350	13,576	1,309	950	368,137	424,270
2010	45,332	81,365	1,399	1,026	424,270	388,610
2011	141,577	24,142	1,330	967	388,610	506,408

Firm Evolution 1991 to 2012









Model Components

Firm Birth

Negative binomial distribution is fitted to the data, for sampling new born

Attributes of employment size and type are sampled at random from population

Firm Death

Binary choice model – firm is the unit of analysis determining the probability of death.

One model specified by controlling for industry type

Within-migration

Binary choice – firm is the unit that determines probability of relocation.

One model specified by controlling for industry type

In-migrate

Determine a **fixed rate** of in-migration from data

Out-migrate

Determine a **fixed rate** of out-migration from data

Growth / Decline

Log-linear specification of employment size

Control for previous year employment to determine future

Location choice

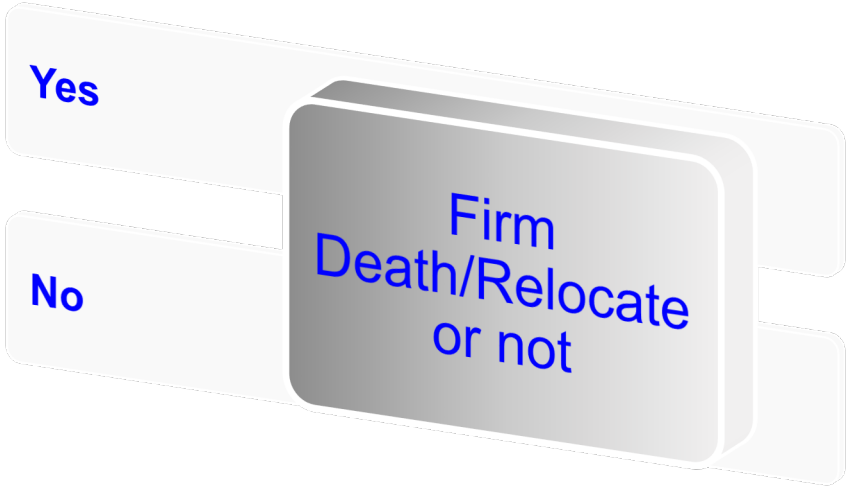
MNL specification with universal utility function

Control for industry type in model specification

Applied to – birth, within-migration and in-migration firms

Firm Death and Relocation (within migration)

Available Set of Choices



Model Structure = Binary Logit

Outputs:

Firm dissolves / relocates or not

Decision-Making Variables

$$y_{it}^{e*} = \alpha' f_{it} + \beta' s_{it} + \gamma' z_{it} + \varepsilon_{it}$$

Internal attributes (f_{it})	Employment, age, subsidiary, change in employment
Sector type (s_{it})	Specific industry
External attributes (z_{it})	Zonal employment

Findings

- Older / larger firms have higher likelihood of survival
- Significantly different across industry types, e.g., construction and food/accommodation services have higher likelihood of failure

Firm Growth Model

Regression Model

Firm Growth (employment size)

Model Structure = Log-linear Model

Outputs:

Firm employment size

Decision-Making Variables

$$\log(e_{it}) = \alpha' \log(e_{i,t-1}) + \beta' f_{it} + \gamma' s_{it} + \theta' z_{it} + \varepsilon_{it}$$

Firm's Internal attributes (f_{it})	Age, subsidiary
Sector type (s_{it})	Specific industry
Employment size ($e_{i,t-1}$)	Employment size for firm '*i*' for time period '*t-1*'

Findings

- Older (age) / larger (employment size) firms tend to grow slow towards saturation
- Previous year employment or growth trajectory influences growth
- Varies by sector, e.g., healthcare, food/accommodation services have higher magnitude of growth

Firm Location Choice Model

Available Set of Choices

Model Structure = MNL

Outputs:
Location TAZ of each firm

Decision-Making Variables

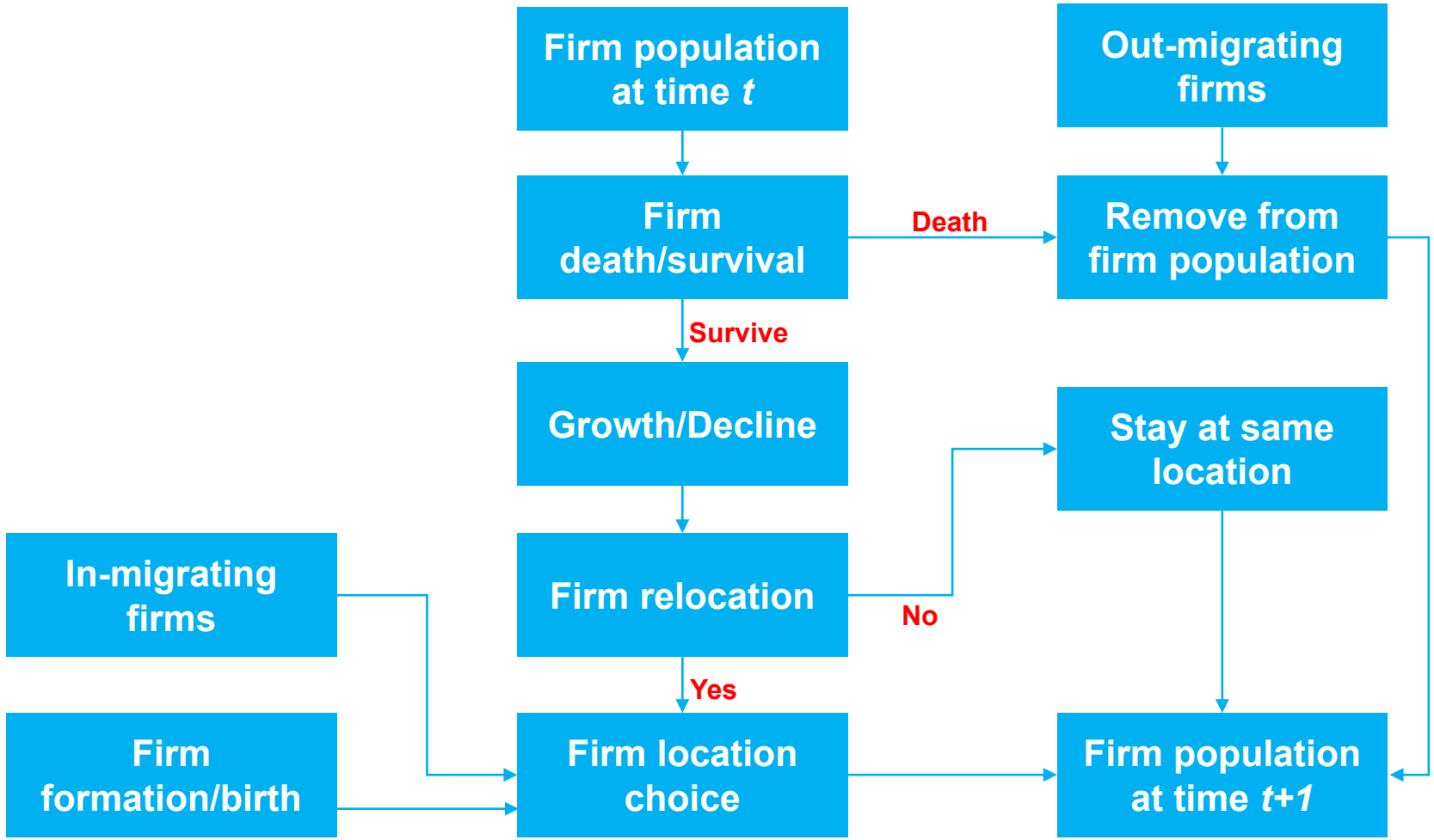
$$U_{in} = V_{in} + \varepsilon_{in} = X_n A_{in} \beta_i + A_{in} \alpha_i + \varepsilon_{in}$$

Firm attributes (X_n)	Age, subsidiary, change in employment
Location choice attributes (A_i)	Employment by industry, population density, miles of freeways, arterials, collector roads
Size variables	Zonal employment by industry, school enrollment

Findings

- Proximity to freeway miles has a positive impact on manufacturing firm location
- Proximity to arterial miles affects transportation/warehouse and wholesale
- Population density has negative impact (not so much for professional services)
- Employment density influences more food / accommodation services

Simulation Framework



Model Validation

Population Aggregates

- County level totals
- NAICS 2-digit Industry types
- Data sources - 2015 InfoGroup and Maricopa County Employer Database (ED)

Simulation of 20% validation sample from NETS

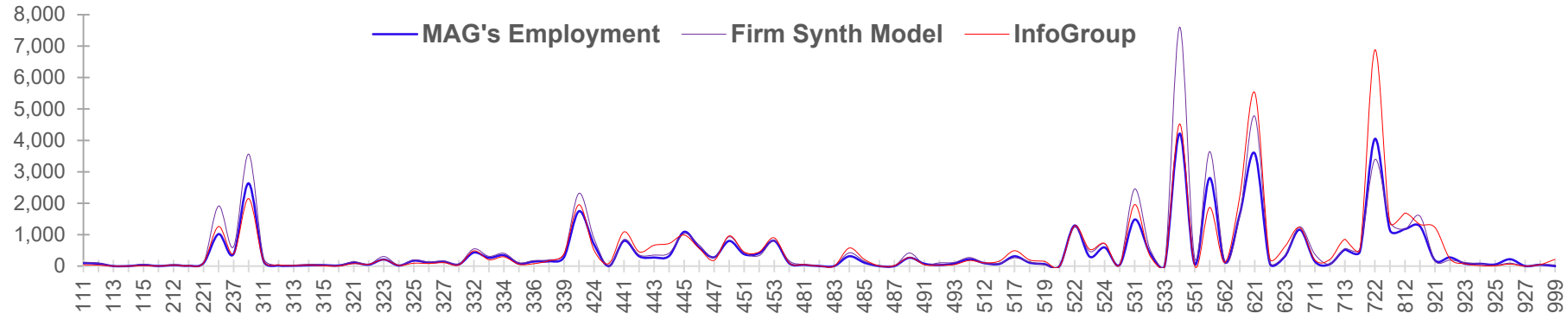
- Firm evolution simulation from 2007 to 2011

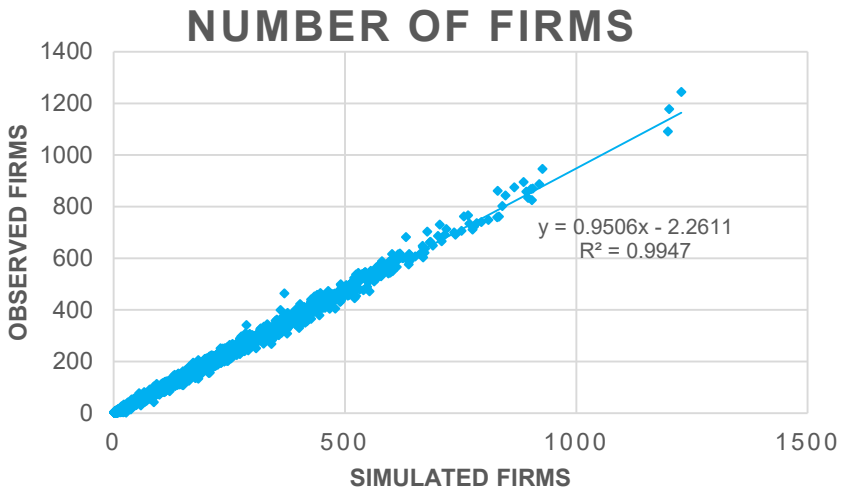
Zonal employment validation

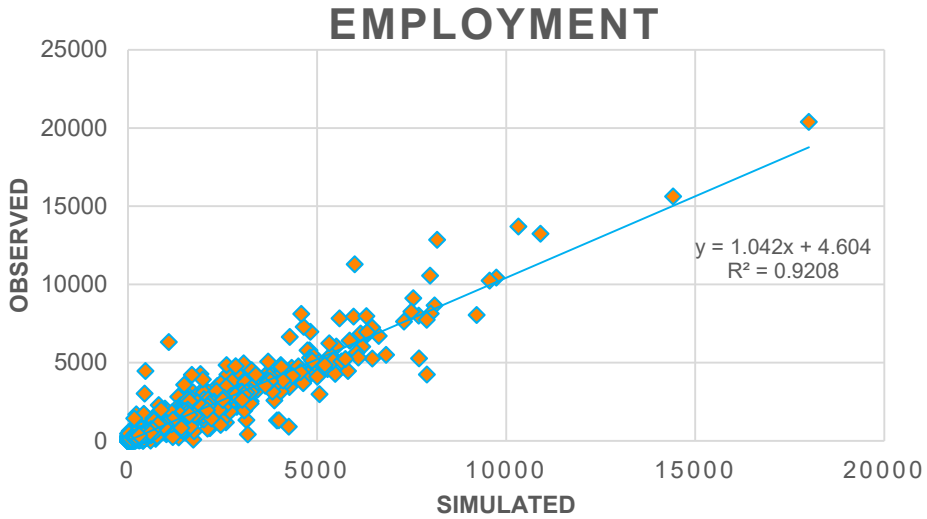
- Spatial distribution with simulated and observed
- Scatter plots by zone by sector types

Firm Synthesizer

Model vs. Observed





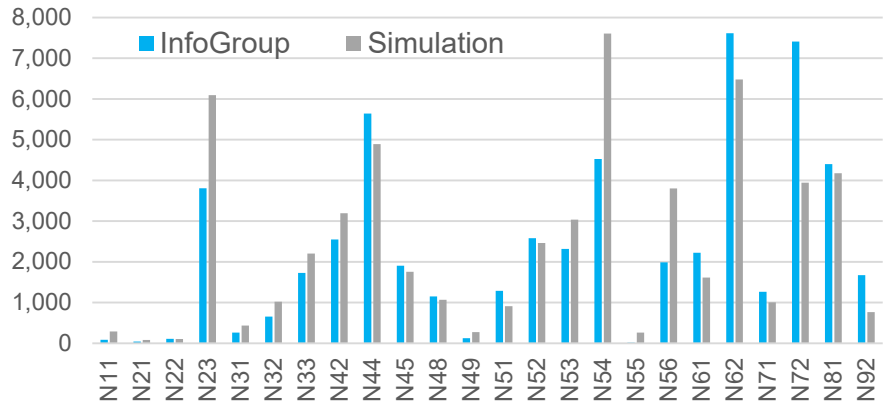


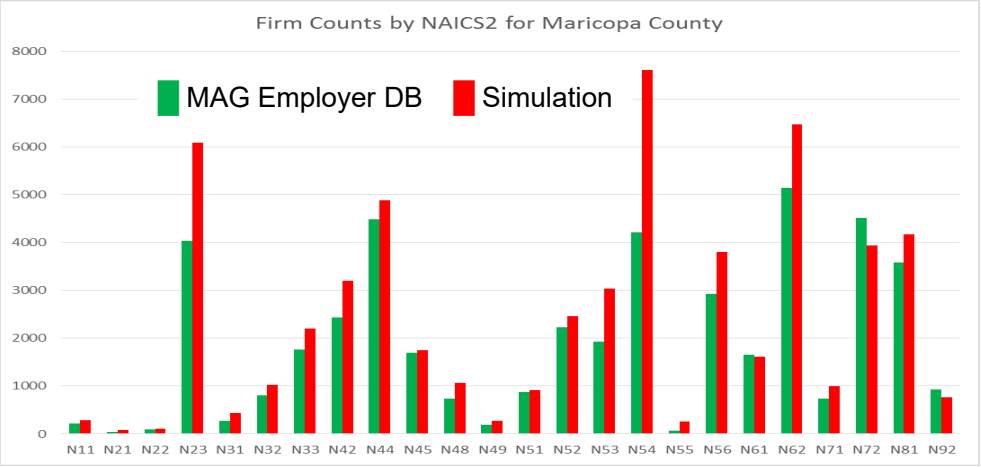
Firm Population Aggregates

InfoUSA

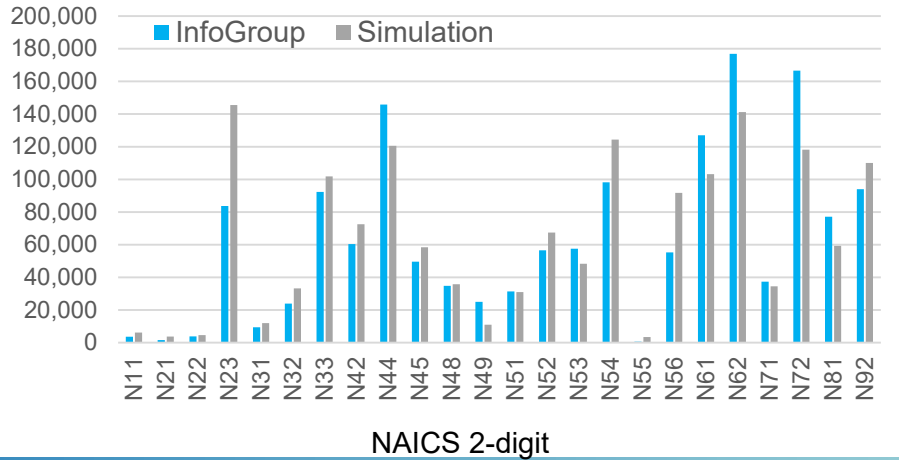
MAG Employer Database

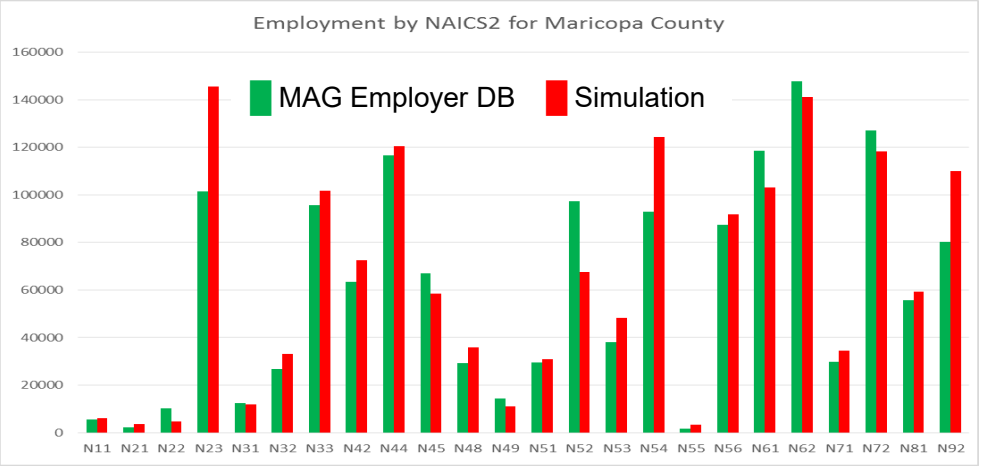
Firm Count for Maricopa County





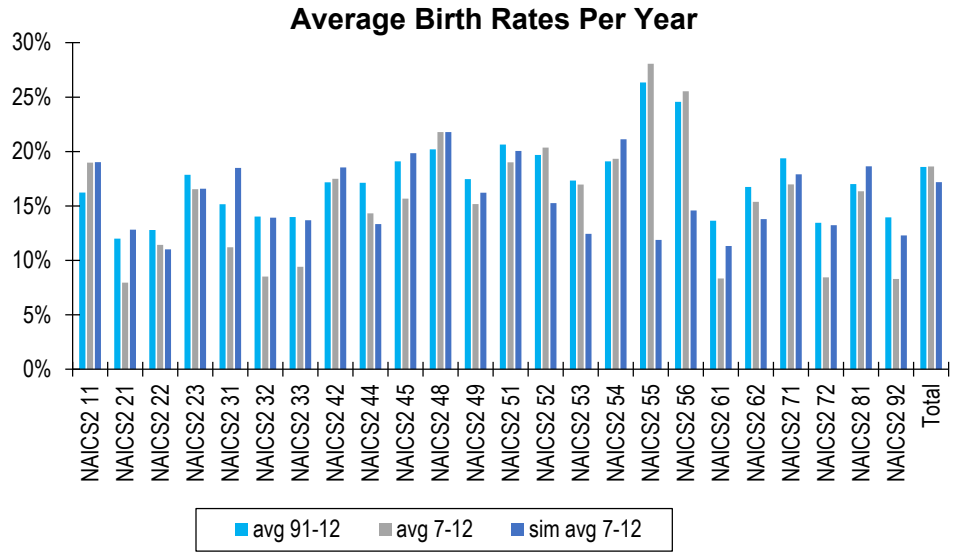
Employment for Maricopa County

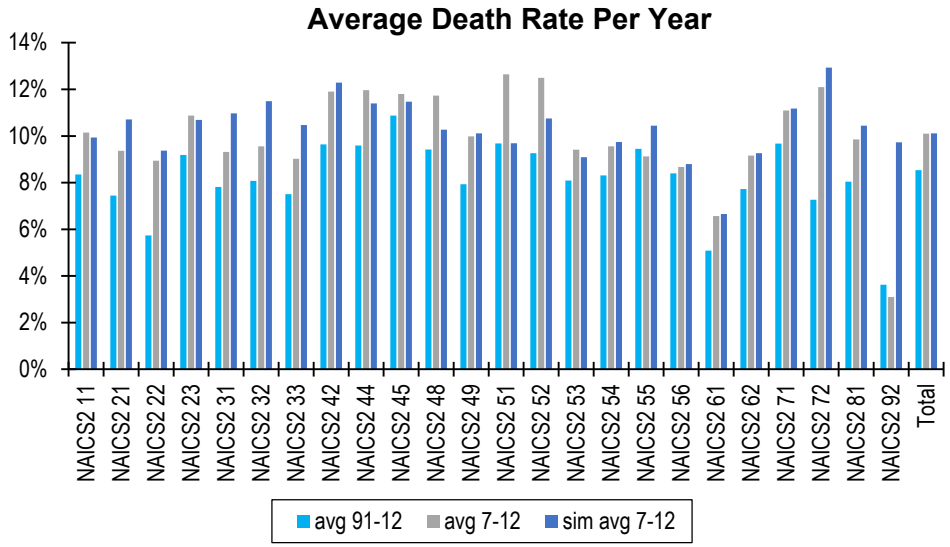




Micro-level Firm Demographic Results

	Year	Firms	Born	Died	Moved	Employment
Observed	2007	59,574	–	–	–	523,492
	2008	69,513	12,640	2,701	1,249	537,425
	2009	66,995	13,786	16,304	1,739	563,071
	2010	71,162	9,027	4,860	1,685	534,760
	2011	88,558	28,328	10,932	1,721	571,373
Simulation	**Year**	**Firms**	**Born**	**Died**	**Moved**	**Employment**
	2007	56,780	–	–	–	492,645
	2008	64,952	13,152	5,995	1,298	495,397
	2009	67,740	8,841	7,207	1,463	486,939
	2010	75,433	13,987	7,498	1,544	500,305
	2011	83,518	15,300	8,552	1,681	503,675
	% Deviation	**-1%**	**-4%**	**-2%**	**0%**	**-6%**





Zonal Employment Post Processing

Post processing of zonal employment

- To accurately predict zonal employment with regional socioeconomic projections
- Calibrating the firm simulation outputs with no outliers

Two Tiered Adjustment

- Employment by sector
  - Firms are removed or duplicated as per employment control totals
- For all TAZs
  - Firms are randomly moved to TAZs that have employment discrepancies
- Scaling of all employment by sector is finally achieved to the observed control total

MAG & PAG zonal employment estimates serve as control totals

- E.g. 2015 Socioeconomic Data

Firm Synthesis - Conclusions

- Firmography approach is better than assuming constant shares for forecast years (as it accounts for formation, relocation, dissolution)
- Simulation & validation results also confirm predictability and reliability of the Firmography framework
- Micro-level and zonal predictions closely resemble observed trends

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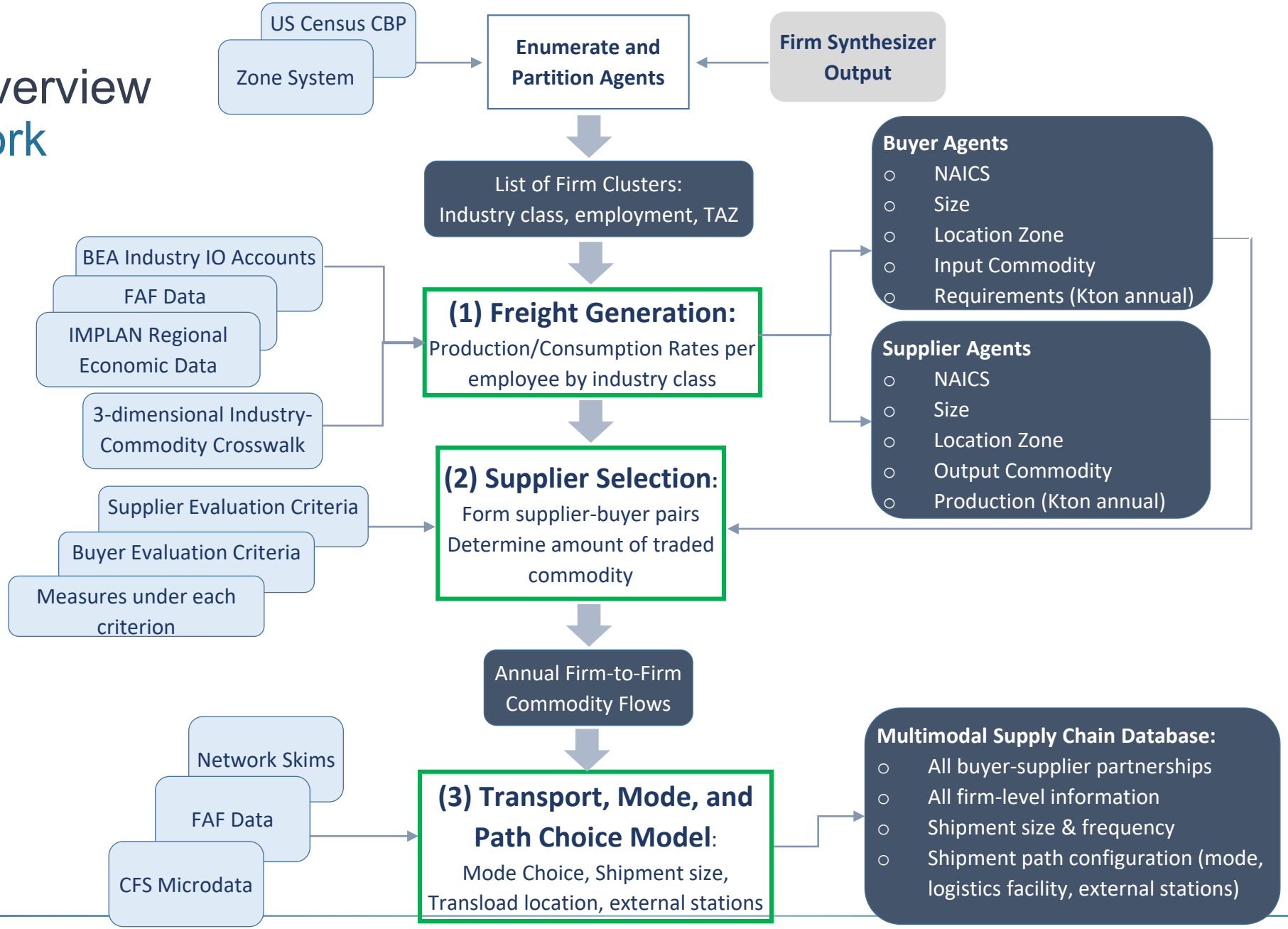
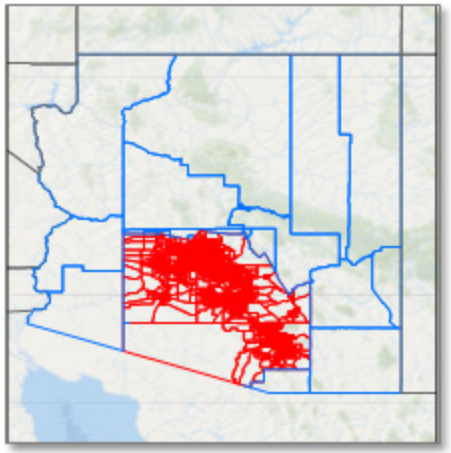
- **Supply Chain Model**
- Value of Advanced Behavioral Freight Models

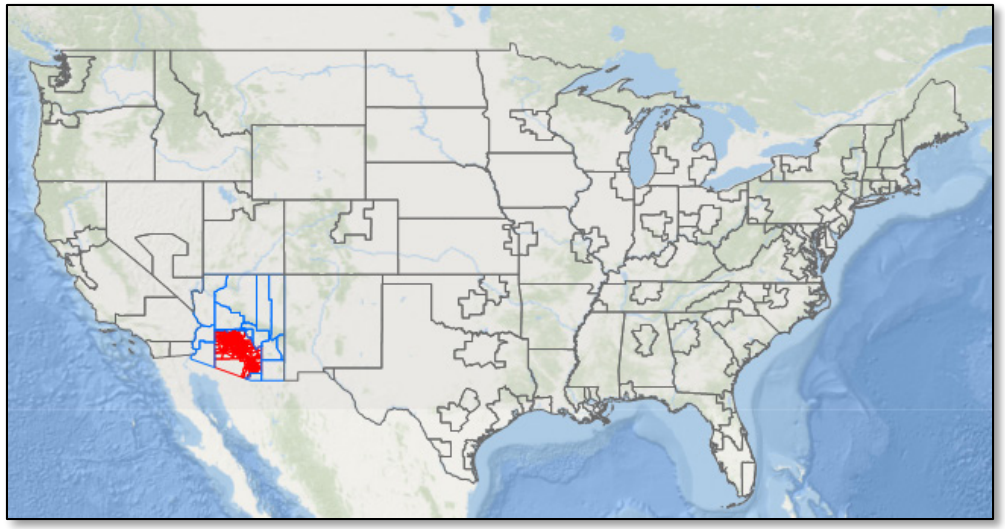
Model Overview
Framework

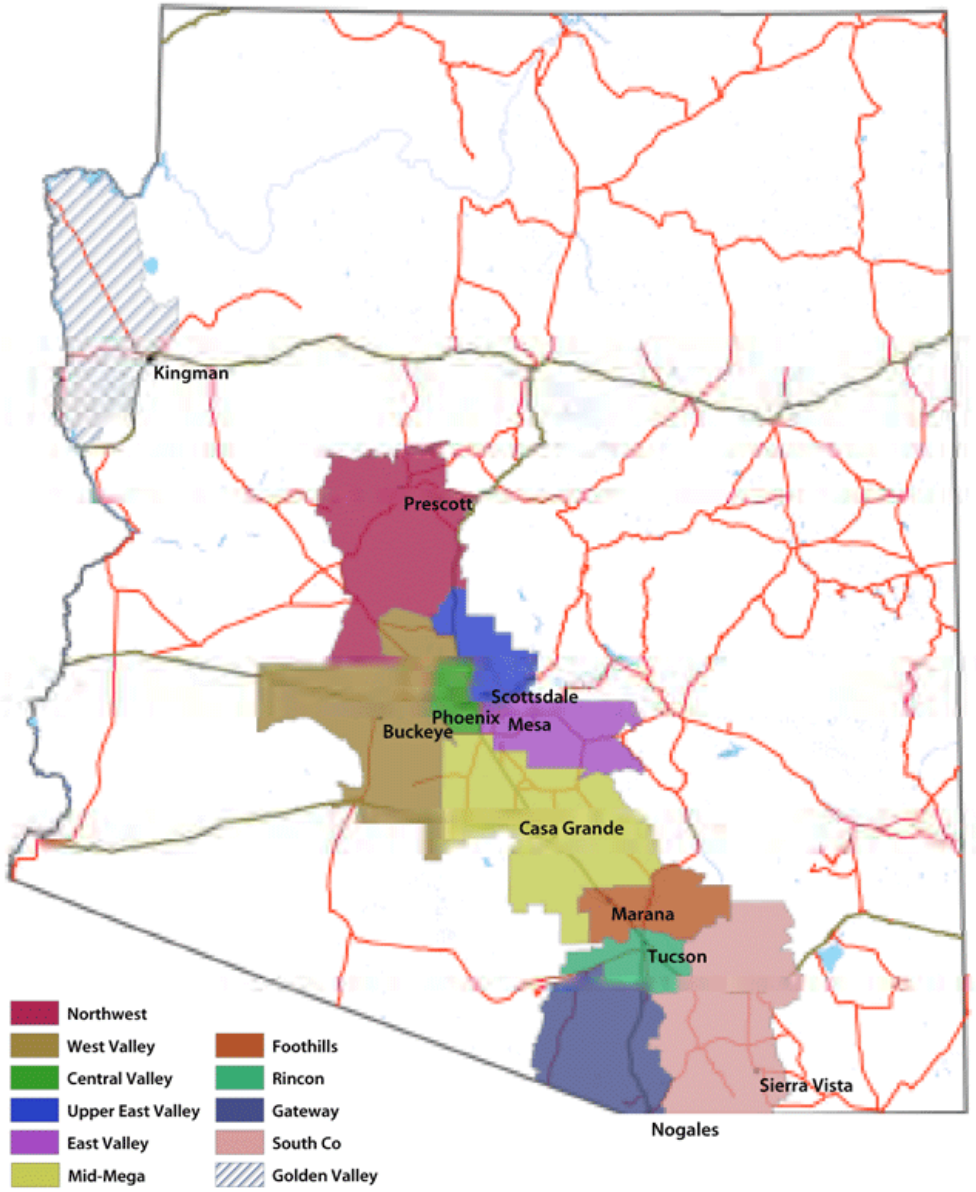


Model Overview
Geography

- Study Area:
  - Arizona Sun Corridor Megaregion (MAG+PAG Modeling Area)
- Variable Zone System:
  - MAG-PAG megaregion: TAZ
  - Rest of Arizona: County
  - Rest of the US: FAF zones







Credit: Morrison Institute for Public Policy, Arizona State University

Model Overview
Input / Agents

- 8.5 million establishments/firms with 6-digit NAICS industry classification
  - Within the study area: Outputs from Firm Synthesizer Model
  - External Firms: County Business Patterns (CBP) data from U.S. Census Bureau
- Partitioned by industry class, employment size, and location
- Down to 398,385 firm clusters (decision-making agents)

NAICS	DESCRIPTION	EMPLOYMENT	ESTABLISHMENTS
11	Agriculture, Forestry, Fishing and Hunting	15,506	5,052
21	Mining, Quarrying, and Oil and Gas Extraction	5,533	432
22	Utilities	8,141	557
23	Construction	193,354	48,038
31-33	Manufacturing	187,468	16,053
42	Wholesale Trade	111,312	18,452
44-45	Retail Trade	288,057	46,665
48-49	Transportation and Warehousing	66,407	9,190
51	Information	54,148	9,899
52	Finance and Insurance	112,249	23,975
53	Real Estate and Rental and Leasing	96,916	25,476
54	Professional, Scientific, and Technical Services	199,234	50,644
55	Management of Companies and Enterprises	9,723	4,214
56	Administrative and Support and Waste Management and Remediation Services	248,484	88,629
61	Educational Services	191,967	17,821
62	Health Care and Social Assistance	223,814	28,275
71	Arts, Entertainment, and Recreation	48,174	8,284
72	Accommodation and Food Services	142,008	8,935
81	Other Services (except Public Administration)	134,471	37,733
92	Public Administration	106,603	1,738
TOTAL		2,443,569	450,062

Model Overview
Traded Goods/ Supply Chain Markets

- 2-digit SCTG
- 42 Commodity Groups

SCTG	Commodity Description	SCTG	Commodity Description
1	Live animals and live fish	22	Fertilizers
2	Cereal grains	23	Chemical products and preparations, n.e.c.
3	Other agricultural products	24	Plastics and rubber
4	Animal feed and products of animal origin, n.e.c.	25	Logs and other wood in the rough
5	Meat, fish, seafood, and their preparations	26	Wood products
6	Milled grain products and preparations, bakery products	27	Pulp, newsprint, paper, and paperboard
7	Other prepared foodstuffs and fats and oils	28	Paper or paperboard articles
8	Alcoholic beverages	29	Printed products
9	Tobacco products	30	Textiles, leather, and articles of textiles or leather
10	Monumental or building stone	31	Nonmetallic mineral products
11	Natural sands	32	Base metal in primary or semi-finished forms and in finished basic shapes
12	Gravel and crushed stone	33	Articles of base metal
13	Nonmetallic minerals n.e.c.	34	Machinery
14	Metallic ores and concentrates	35	Electronic and other electrical equipment and components and office equipment
15	Coal	36	Motorized and other vehicles (including parts)
16	Crude Petroleum	37	Transportation equipment, n.e.c.
17	Gasoline and aviation turbine fuel	38	Precision instruments and apparatus
18	Fuel oils	39	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs
19	Coal and petroleum products, n.e.c.	40	Miscellaneous manufactured products
20	Basic chemicals	41	Waste/Scrap
21	Pharmaceutical products	43	Mixed Freight

(1) Freight Generation
Firm-level Production and Consumption

- Input Data
  - Regional Economic Data by IMPLAN
  - BEA 2007 Industry Input-Output Accounts data
  - Employment data Firm Synthesizer and CBP
  - Commodity-Industry crosswalks
  - FAF Data

- Implementation
  - Supplier/Buyer Status
  - Type and amount of commodities produced (supply) & consumed (demand)

(1) Freight Generation
Procedure

Develop Commodity-Industry Crosswalks (NAICS-SCTG & IO-SCTG)	• Commodity-Industry crosswalk • IO crosswalk
Identify produced and consumed commodities by industry (supplier/buyer status)	• 3-dimensional correspondence system
Calculate production and consumption rates by employee by industry	• Employment data • BEA Input-Output Accounts data
Convert Monetary rates to tons	• Unit value of commodities from FAF data
Calculate annual production and consumptions for each firm and calibrate	• Firm database • FAF Production/Consumption Data

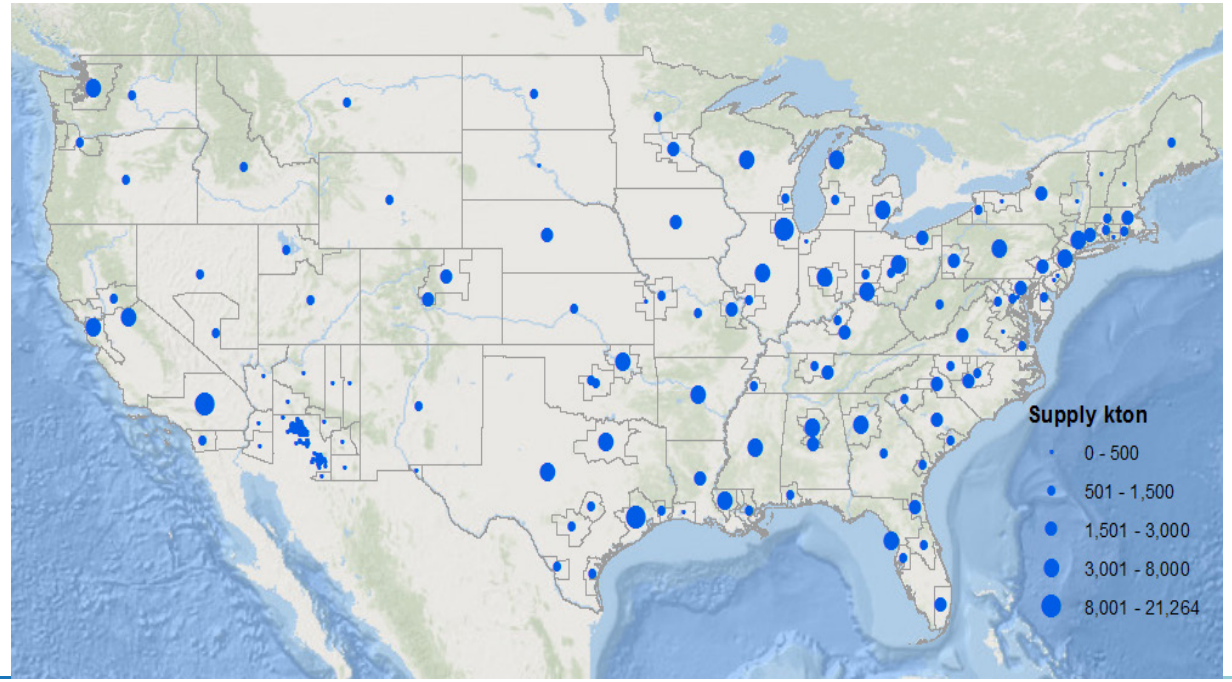
(1) Freight Generation

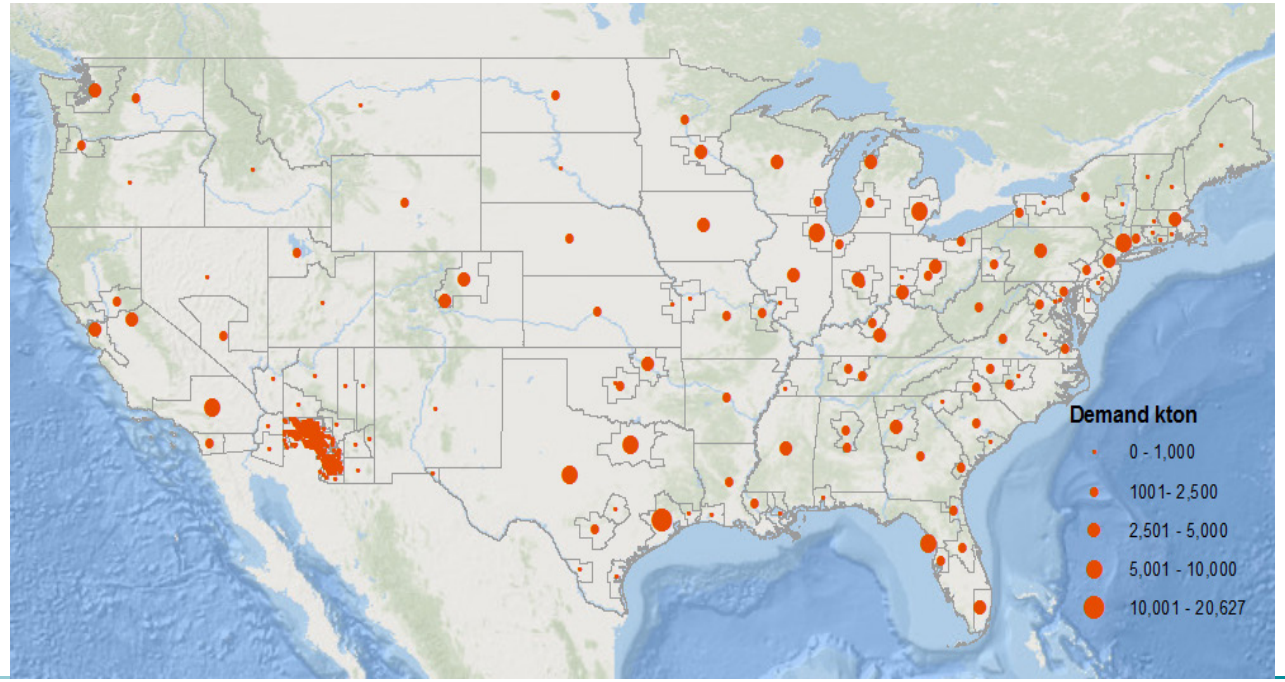
Output: Supplier & Buyer Firms Database

- Firms characteristics
- SCTG
- Supply/Demand K-ton

Total National Supply & Demand	18,040,435 k-ton
MAG-PAG Supply	125,029 k-ton
MAG-PAG Demand	163,861 k-ton
Simulated Supplier Agents	137,328
Simulated Buyer Agents	4,177,042

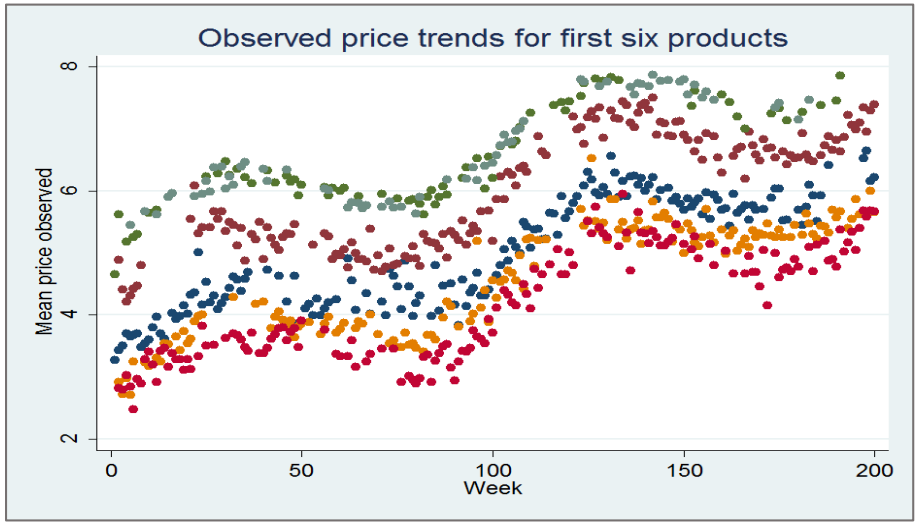
Freight Generation Results for Articles of Base Metal (SCTG 33)

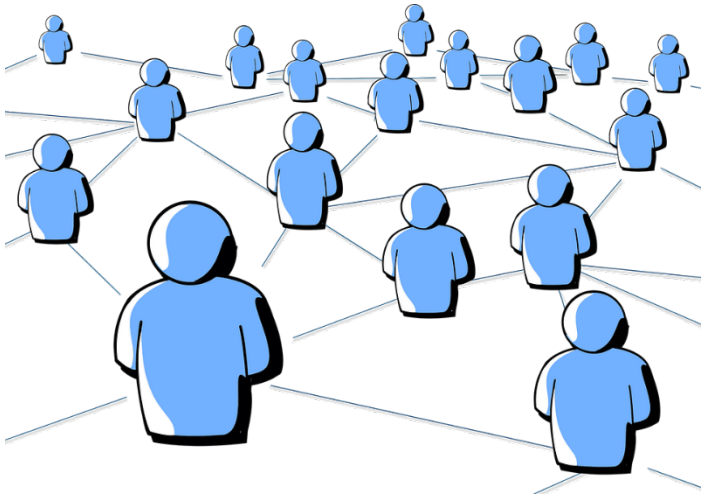




(2) Supplier Selection
Alternative Methods

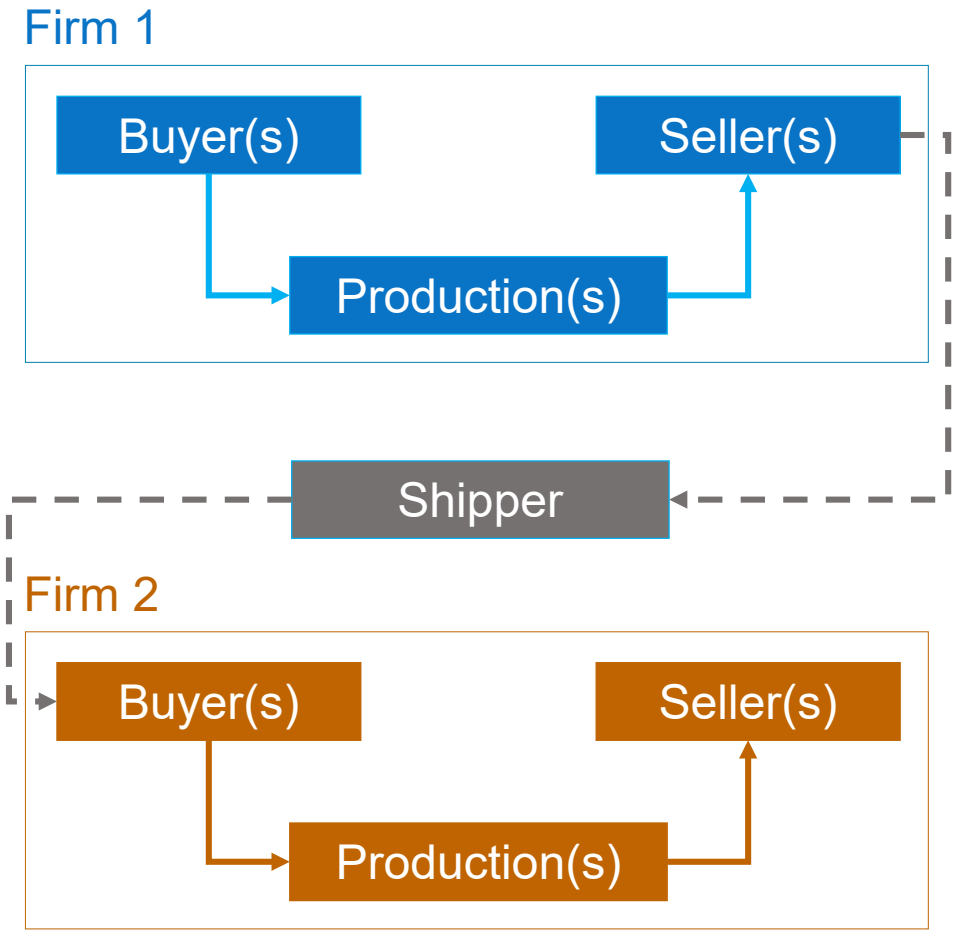
- Multi-objective optimization (MOP)
- Analytic hierarchy process (AHP)
- Data envelopment analysis (DEA)
- Simple multi-attribute rating technique (SMART)
- Agent-based market simulation – simulated buying-selling (market) relationships calibrated to data





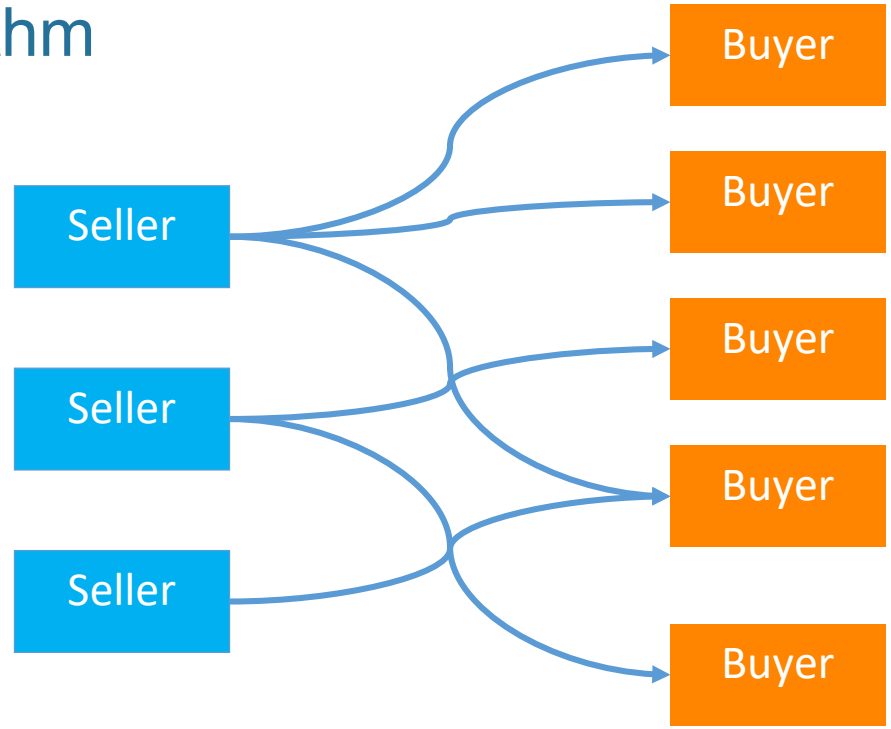
(2) Supplier Selection
Agent Modeling Constructs

- Multiple agents (actors) interact in the market
- Firms buy commodities, produce using them and other commodities, and then sell and transport these goods.
- Agent model is a simplified portion of this ”enterprise” model, focusing on the buyers and sellers in individual commodity markets



(2) Supplier Selection
Market Clearing Model - Roth & Peranson Algorithm

- A pareto-optimal and stable market-clearing mechanism to matches buyers to sellers.
- Only needs an ordinal ranking of who each buyer would like to purchase from, and an ordinal ranking of whom each seller would like to sell to.
- Selection Utility/Score is calculated for each buyer and seller

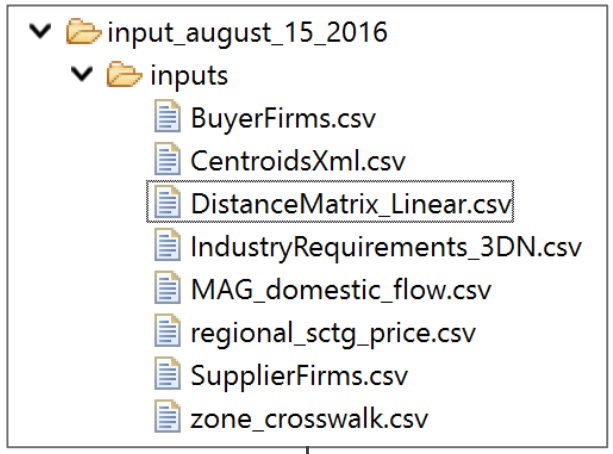


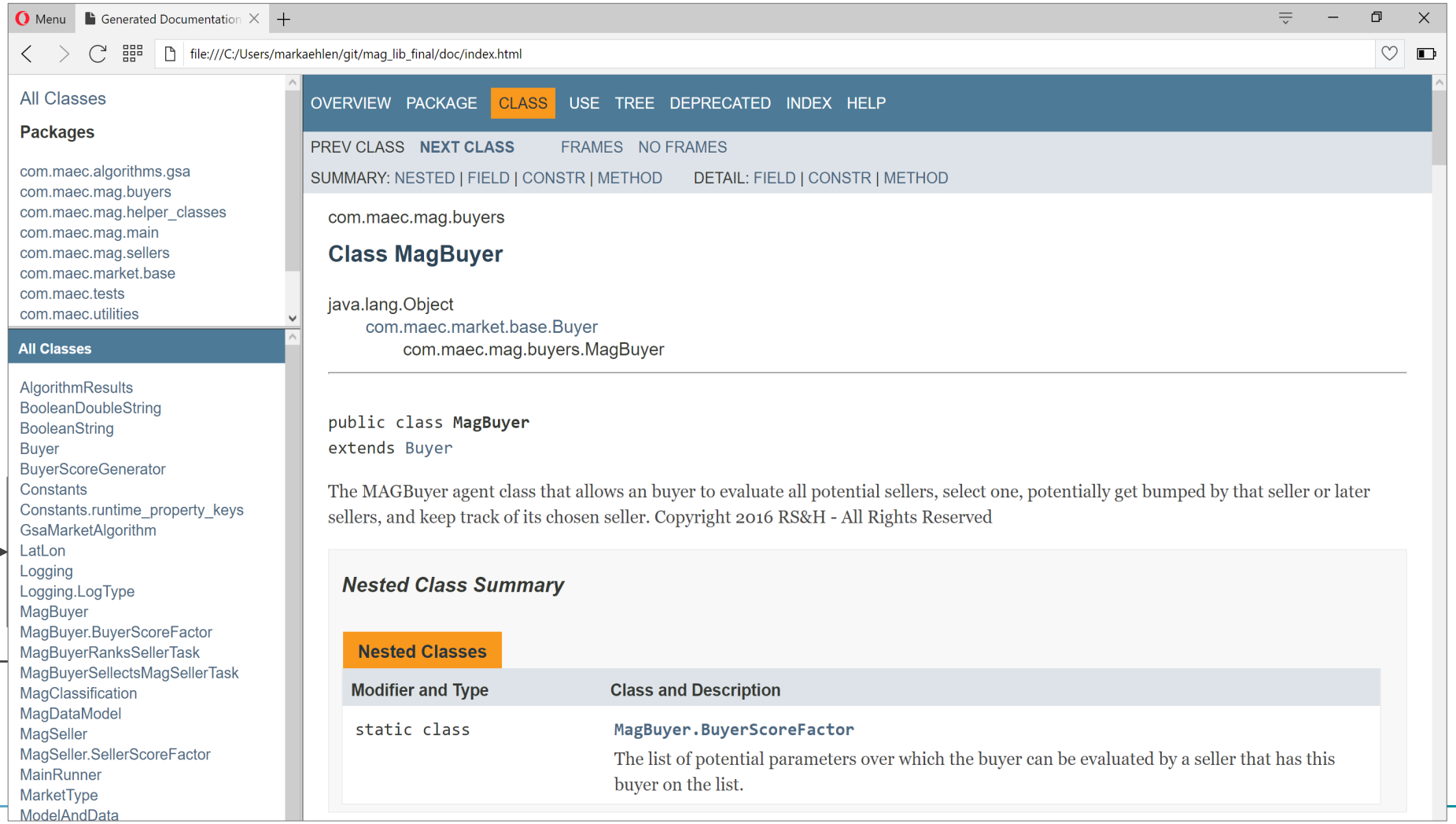

```
public static enum SellerScoreFactor {

    INVERSE_DISTANCE,
    AVG_PRODUCTION,
    AVG_EMPLOYEE_SIZE,
    INVERSE_SELLER_PRICE,
    SELLER_PRODUCTION;
}
```

```
public static enum BuyerScoreFactor {

    BUYER_AVG_EMPLOYEE_SIZE,
    BUYER_AVG_DEMAND,
    BUYER_EMPLOYEE_SIZE,
    BUYER_DEMAND
}
```

Reference: Roth, Alvin & Elliott Peranson (September 1999). “The Redesign of the Matching Market for American Physicians: Some Engineering Aspects of Economic Design” (PDF). The American Economic Review 89 (4): 756–757. doi:10.1257/aer.89.4.748.

(2) Supplier Selection
Software Implementation and Documentation





(2) Supplier Selection
Output

AllBuyers_15_15 - Excel

E3 | 2167

SCTG	buyer_id	buyer_naics	buyer_mag_zone	buyer_faf	buyer_empSize	buyer_employees	buyer_estabs	seller_id	seller_naics	seller_mag_zone	seller_faf	seller_empSize	seller_employ	seller_estabs	purchases_ktns
15	4194368	541110	2191	41	1	5	2	4223584	212111	9132	300		1	1	1.33E-05
15	4194369	541110	2167	41	1	14	4	4223584	212111	9132	300		1	1	3.71E-05
15	4194370	541110	2179	41	1	14	3	4223584	212111	9132	300		1	1	3.71E-05
15	4194371	541110	2581	41	1	2	1	4223584	212111	9132	300		1	1	5.30E-06
15	4194372	541110	2582	41	1	3	1	4223584	212111	9132	300		1	1	7.95E-06
15	4194373	541110	2550	41	1	3	1	4223584	212111	9132	300		1	1	7.95E-06
15	4194374	541110	2576	41	1	2	1	4223584	212111	9132	300		1	1	5.30E-06
15	4194375	541110	2611	41	1	10	5	4223584	212111	9132	300		1	1	2.65E-05
15	4194376	541110	2619	41	1	2	1	4223584	212111	9132	300		1	1	5.30E-06
15	4194377	541199	2584	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06
15	4194378	541110	2599	41	1	2	1	4223584	212111	9132	300		1	1	5.30E-06
15	4194379	541110	2689	41	1	3	1	4223584	212111	9132	300		1	1	7.95E-06
15	4194380	541110	2692	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06
15	4194381	541110	2657	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06
15	4194382	541199	2658	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06
15	4194383	541110	2711	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06
15	4194384	541110	2720	41	1	3	1	4223584	212111	9132	300		1	1	7.95E-06
15	4194385	541110	2700	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06
15	4194386	541110	2709	41	1	13	5	4223584	212111	9132	300		1	1	3.45E-05
15	4194387	541110	2399	41	1	3	1	4223584	212111	9132	300		1	1	7.95E-06
15	4194388	541110	2405	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06
15	4194389	541110	2386	41	1	4	1	4223584	212111	9132	300		1	1	1.06E-05
15	4194390	541110	2398	41	1	2	2	4223584	212111	9132	300		1	1	5.30E-06
15	4194391	541110	2432	41	1	1	1	4223584	212111	9132	300		1	1	2.65E-06

(3) Transport, Mode and Path Choice Model
Overview

- Disaggregate Logistics Choice Model
- Evaluates alternatives for each buyer-supplier pair
- Joint Mode and Shipment Size Choice
- Main estimation source: 2012 Commodity Flow Survey (CFS) Microdata Sample
- Determine external stations for highway mode and Selected Intermodal Yard for Rail shipments

(3) Transport, Mode and Path Choice Model
Data Sources: 2012 CFS Microdata

Mode	Use in Model Estimation and Application	N
Truck	Yes (combine)	1
For-hire truck		35,038
Private truck		28,805
Rail	Yes (combine)	501
Truck and rail		161
Air (incl truck & air)	Yes (combine)	2,863
Parcel, USPS, or courier		34,107
Mode suppressed	No - unknown mode	5
Single mode	No - unknown mode	221
Multiple mode	No - unknown mode	135
Truck and water	No - water not included	1
Non-parcel multimode	No - unknown mode	4
All Shipment Records		**101,842**
Shipment Records with Complete Mode Information		**101,476**

(3) Transport, Mode and Path Choice Model
Shipments by Mode

Mode	N Shipment	% Total Tons		Mean Tons per Shipment	
		Unweighted	Weighted	Unweighted	Weighted
truck	63,844	36.42	83.69	6.2	1.6
rail	662	62.44	14.53	1,046	173
parcel/air	36,970	0.05	0.49	0.0162	0.0002
Total Tons (Millions)		Unweighted		Weighted	
		1.10		149.51	

(3) Transport, Mode and Path Choice Model

Geographical distribution of Arizona-based shipment

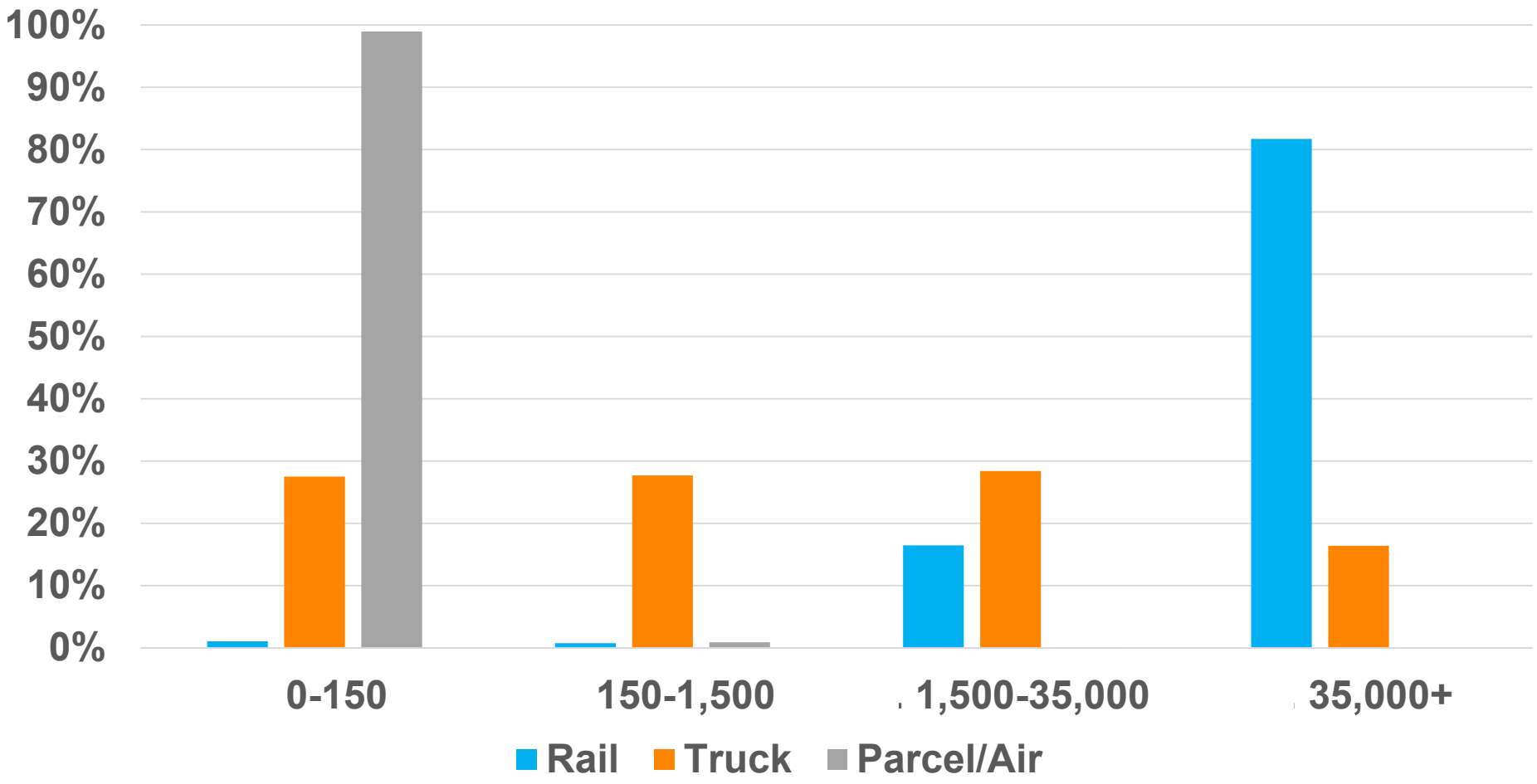
Origin Region	Destination Region															
	Sun Corridor - Phoenix and Tucson	Remainder of Arizona	California - Southern	California - Other	Nevada	Utah	Colorado	New Mexico	Pacific Northwest	Central-Upper Midwest	Great Lakes	Northeast U.S.	Texas and Oklahoma	Southeast U.S.	Alaska and Hawaii	Total
Sun Corridor - Phoenix and Tucson	26,498	2,407	3,868	1,585	633	407	562	735	1,084	1,127	2,150	2,506	2,617	3,071	76	49,326
Remainder of Arizona	1,407	9,076	1,381	889	468	205	321	287	429	479	636	625	665	838	30	17,736
California - Southern	4,210	576	-	-	-	-	-	-	-	-	-	-	-	-	-	4,786
California - Other	2,235	436	-	-	-	-	-	-	-	-	-	-	-	-	-	2,671
Nevada	888	280	-	-	-	-	-	-	-	-	-	-	-	-	-	1,168
Utah	932	189	-	-	-	-	-	-	-	-	-	-	-	-	-	1,121
Colorado	639	194	-	-	-	-	-	-	-	-	-	-	-	-	-	833
New Mexico	446	286	-	-	-	-	-	-	-	-	-	-	-	-	-	732
Pacific Northwest	1,356	242	-	-	-	-	-	-	-	-	-	-	-	-	-	1,598
Central-Upper Midwest	2,370	581	-	-	-	-	-	-	-	-	-	-	-	-	-	2,951
Great Lakes	4,565	698	-	-	-	-	-	-	-	-	-	-	-	-	-	5,263
Northeast U.S.	4,708	558	-	-	-	-	-	-	-	-	-	-	-	-	-	5,266
Texas and Oklahoma	2,169	481	-	-	-	-	-	-	-	-	-	-	-	-	-	2,650
Southeast U.S.	4,624	769	-	-	-	-	-	-	-	-	-	-	-	-	-	5,393
Alaska and Hawaii	65	17	-	-	-	-	-	-	-	-	-	-	-	-	-	82
Arizona-Unknown Region	43	28	36	9	1	4	3	5	10	3	16	13	19	32	23	245
California-Unknown Region	17	4	-	-	-	-	-	-	-	-	-	-	-	-	-	21
Total	57,172	16,822	5,285	2,483	1,102	616	886	1,027	1,523	1,609	2,802	3,144	3,301	3,941	129	101,842

Frequency Missing = 22

Source: CFS 2012 Microdata summarized by the RS&H, Inc. team.

(3) Transport, Mode and Path Choice Model

Distribution of Shipments by Mode Across Shipment Size



(3) Transport, Mode and Path Choice Model

Value per pound categories used in model estimation

Mode	Value ($) per Pound			Total Sample Shipments by Mode	% Sample Shipments by Mode
	LOW (<$1/lb.)	MED ($1-$3.99)	HIGH ($4+/lb.)		
Rail/IMX	83%	17%	0%	614	0.60%
Truck	38%	30%	32%	63,250	63%
Parcel/Air	1%	8%	91%	36,837	36%
Total Number of Shipments in Estimation Sample	24,941	22,166	53,594	100,701	100%
% Sample Shipments by Value Category	25%	22%	53%	100%	

(3) Transport, Mode and Path Choice Model
Travel Time Inputs & Assumptions

Geography	Mode	Distance	Travel Time	Speed (MPH)
All Trips	Rail	Routed	12 hours + IVT* + (12 hours x Number of Trackage Changes)	22
Intra-Sun Corridor	Truck	Routed	4 hours + IVT	20
	Parcel or Air	Routed	1 hour + IVT	40
External	Truck, 0-650 mi.	Routed	16 hours + IVT	65
	Truck, 651-1,299 mi.	Routed	16 hours + IVT	38
	Truck, 1,300+ mi.	Routed	16 hours + IVT	32
	Parcel or Air	Great Circle	12 hours + IVT	250

* IVT = In-vehicle time = distance / speed

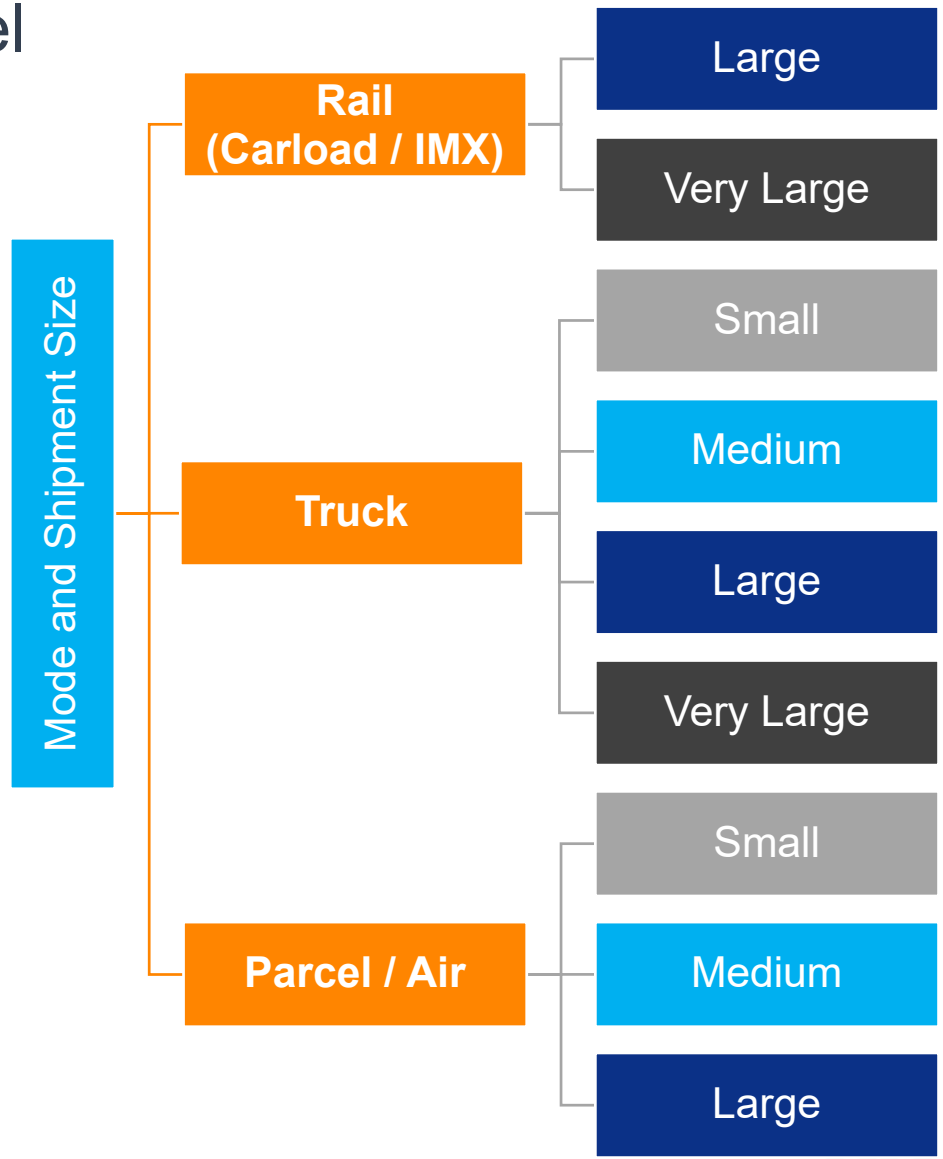
(3) Transport, Mode and Path Choice Model
Transportation Costs

Alternative(s)	Distance	Cost per Ton-Mile	Minimum Cost ($)
Rail	Routed	$0.0395	200
Truck 1 (<150 lbs.)	Great Circle	$2.83	10
Truck 3 (150-1,499 lbs.)	Great Circle	$0.50	15
Truck 4-5 (1,500+ lbs.)	Great Circle	$0.18	15
Parcel or Air 1 (<150 lbs.)	Great Circle	$2.83	10
Parcel or Air 3-4 (150+ lbs.)	Great Circle	$2.09	15

* Cost per ton-mile from RITA and on-line shipping rate data

(3) Transport, Mode and Path Choice Model
Nested Logit structure

Mode Alternatives	Shipment Size Categories			
	SMALL < 150 lbs.	MEDIUM 150-1,499 lbs.	LARGE 1,500-34,999 lbs.	VERY LARGE 35,000+ lbs.
Rail Carload / IMX	Not included	Not included	**Modeled**	**Modeled**
Truck	**Modeled**	**Modeled**	**Modeled**	**Modeled**
Parcel / Air	**Modeled**	**Modeled**	**Modeled**	Not included



(3) Transport, Mode and Path Choice Model
Estimation Results

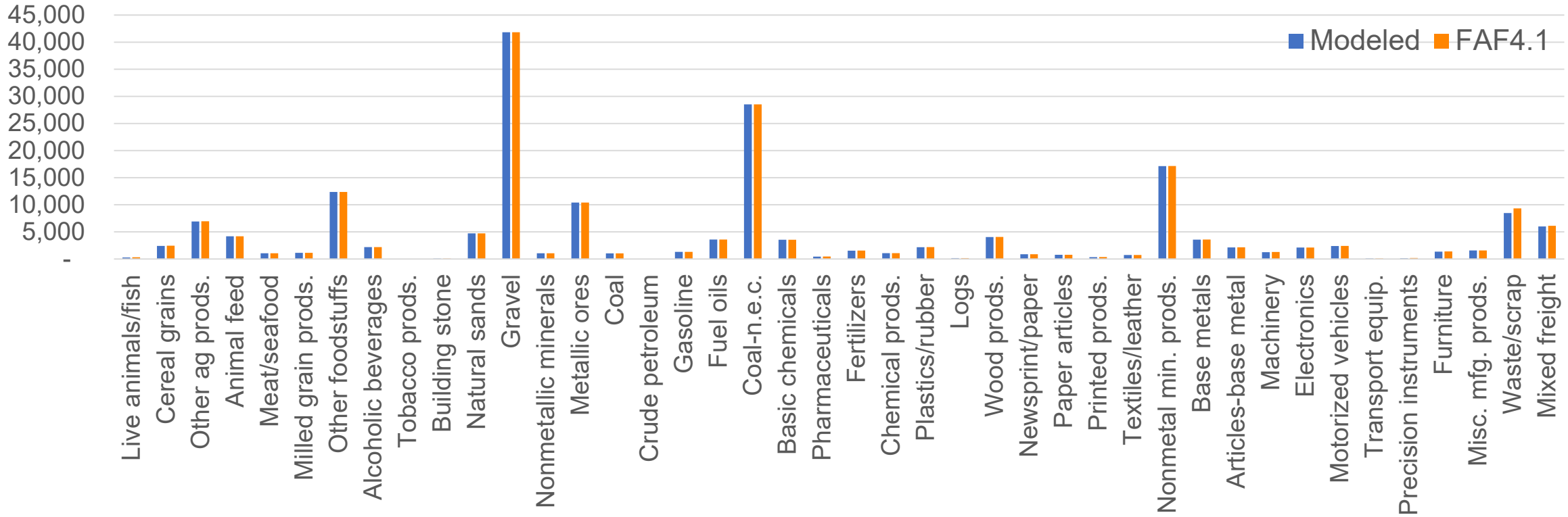
Alternatives	Variables & Estimated Parameters														
	Alternative-Specific Constant (ASC)	Commodity Categories				Export				Transportation Cost (2012 $)			Time (Hours)		
		Bulk Goods	Fuels and Fertilizers	Inter-mediate Products, Foodstuffs and Misc.	Manufactured Goods	Mexico	Canada	Other: All Goods	Other: Increment for High-Value Goods	Low-Value*** Goods	Medium-Value Goods	High-Value Goods	Low-Value Goods	Medium-Value Goods	High-Value Goods
Rail-large	-15.8**	N/A	N/A	0	-30.7**	N/A	N/A	N/A	N/A	-0.0002**	-0.0057**	-0.0063**	0	-0.130**	-0.170**
Rail-very large	-14.6**	8.47**	9.75**	0		N/A	N/A	N/A	N/A						
Truck-small	0	0	0	0	0	0	0	0	0						
Truck-medium	0.287**	0	1.15**	0	-1.14**	0	-0.536**	0	0						
Truck 4-large	-0.106**	2.63**	2.96**	0	-1.98**	0	-1.59**	0	0						
Truck 5 very large	-0.777**	4.90**		0	-3.10**	1.10**		0.173*	0						
Parcel/Air-small	-5.60**	0	0	0	3.47**	-2.73**	-1.62**	6.30**	2.63**						
Parcel/Air-medium	-11.1**	N/A	N/A	0	3.37**	N/A	N/A	10.6**	1.42**						
Parcel/Air-large	-11.6**	N/A	N/A	0	-1.20*	N/A	N/A		0						

* indicates 75% or higher; **indicates 98% or higher statistical significance;
*** Low-value is used for goods that are valued at less than $1/lb.; Medium for $1 to less than $4/lb.; and High for $4+/lb.

(4) Model Calibration: Process

- Freight Analysis Framework (FAF) 4.1 is the main data source.
- Tuning the formation of potential suppliers and buyers sets to minimize the discrepancy
- Comparison of modal split and commodity flow aggregately at FAF zone level between modeled and FAF data

(4) Model Calibration/ Replication: Commodity Flows



MODELED VS. OBSERVED TOTAL DIRECTIONAL FLOWS

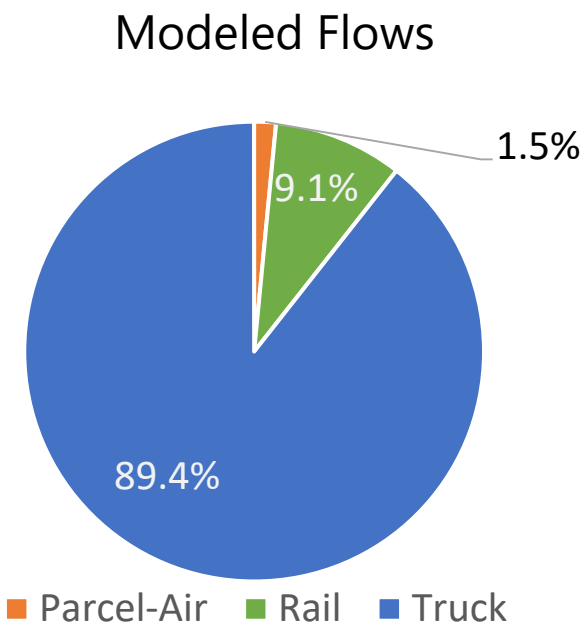
(a) Modeled Flows

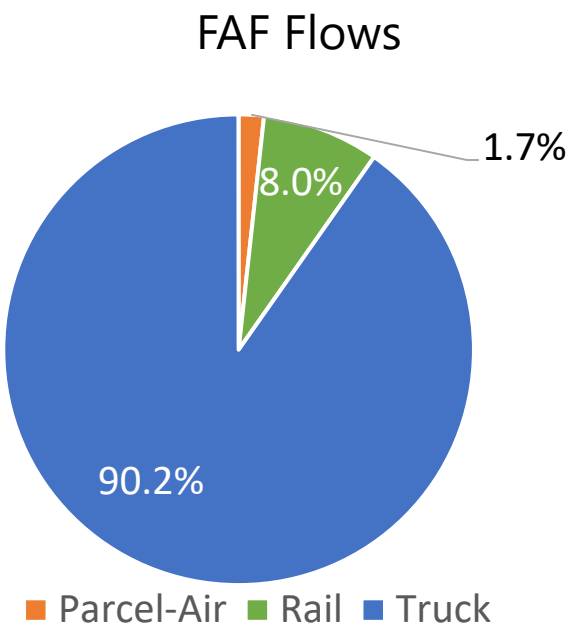
Direction	Flow (kton)	% of Total
II (Internal)	103,945	56%
EI (Inbound)	59,916	32%
IE (outbound)	21,083	12%
Total	184,944	

(b) FAF Flows

Direction	Flow (kton)	% of Total
II (Internal)	104,836	56%
EI (Inbound)	60,038	32%
IE (outbound)	21,548	12%
Total	186,423	

(4) Model Calibration / Replication: Modal Split





Modeled Flows

Direction	Truck	Rail	Parcel/Air
II (Internal)	92.9%	6.0%	1.1%
EI (Inbound)	90.0%	7.1%	2.9%
IE (outbound)	80.3%	19.7%	0.0%
total	89.4%	9.1%	1.5%

FAF Flows

Direction	Truck	Rail	Parcel/Air
II (Internal)	94.9%	4.9%	0.1%
EI (Inbound)	83.2%	12.8%	4.1%
IE (outbound)	87.0%	10.0%	3.0%
total	90.2%	8.0%	1.7%

Outline

- Project and Team Introduction
- Visualization
- Firm Synthesis
- Supply Chain Model
- **Value of Advanced Behavioral Freight Models**

Value of advanced behavioral freight models and some observations from the model development process

- State-of-the-practice truck trip forecasting procedures are not suitable for modeling advanced economic scenarios and technological changes. These tasks require more sensitive tools with higher behavioral fidelity, broader spatial coverage and multimodal simulation.
- Increased model sensitivity and explicit behavioral modeling on micro-level is especially important for large mega-regions at times of non-incremental disruptive transformational changes in economy or technology.
- Models are natural data integrators: they bring structure into data integration problems. Model development process leads to data and information discovery.
- Model development process has value of its own. It facilitates freight data integration and analysis improves communications between freight planning, freight data and freight modeling communities. It also leads to in-depth analysis of freight systems.
- Big Data and new agent-based and microsimulation demand models qualitatively change needs and approaches for data integration.
- Increased fidelity of models (agent-based, micro-simulation) leads to merging of models and data.
- Visualization and analytical tools are a necessity for quality control and analysis of the complex model outputs and large input datasets.

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TMIP Webinar Series

November 15, 2017

Presentation 2: MAG Regional Microsimulation Model

Presented by:

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Daniel Morgan, Caliper Corporation

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Project Team and Contributors:

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MARICOPA ASSOCIATION of GOVERNMENTS

Arup Dutta

Bob Hazlett

Shuyao Hong

Shuo Wang

Wang Zhang

Project Background

- First model was developed for the Central Phoenix Transportation Framework Study for the inner core of the region.
- Subsequently expanded to cover the whole modeling area.
- Region-wide data collection (signals, calibration and validation data).
- Data and model outputs visualizations.
- Applied for a number of large sub-area studies and local traffic impact studies.

(1) Regional Microsimulation Model Development, Calibration, and Validation

Daniel Morgan

Caliper Corporation

Objectives

- Model Development
  - Geography, geometry development
  - Centroid, centroid connector development
  - Traffic count data preparation
  - Signal timing data preparation
- Calibration to Counts
  - Year 2015 target
  - Calibrate to 15-minute counts (some dating to 2012)
- Validation
  - Validate to 15-minute speeds (NPRDMS 2015 weekday)
  - Match key bottlenecks

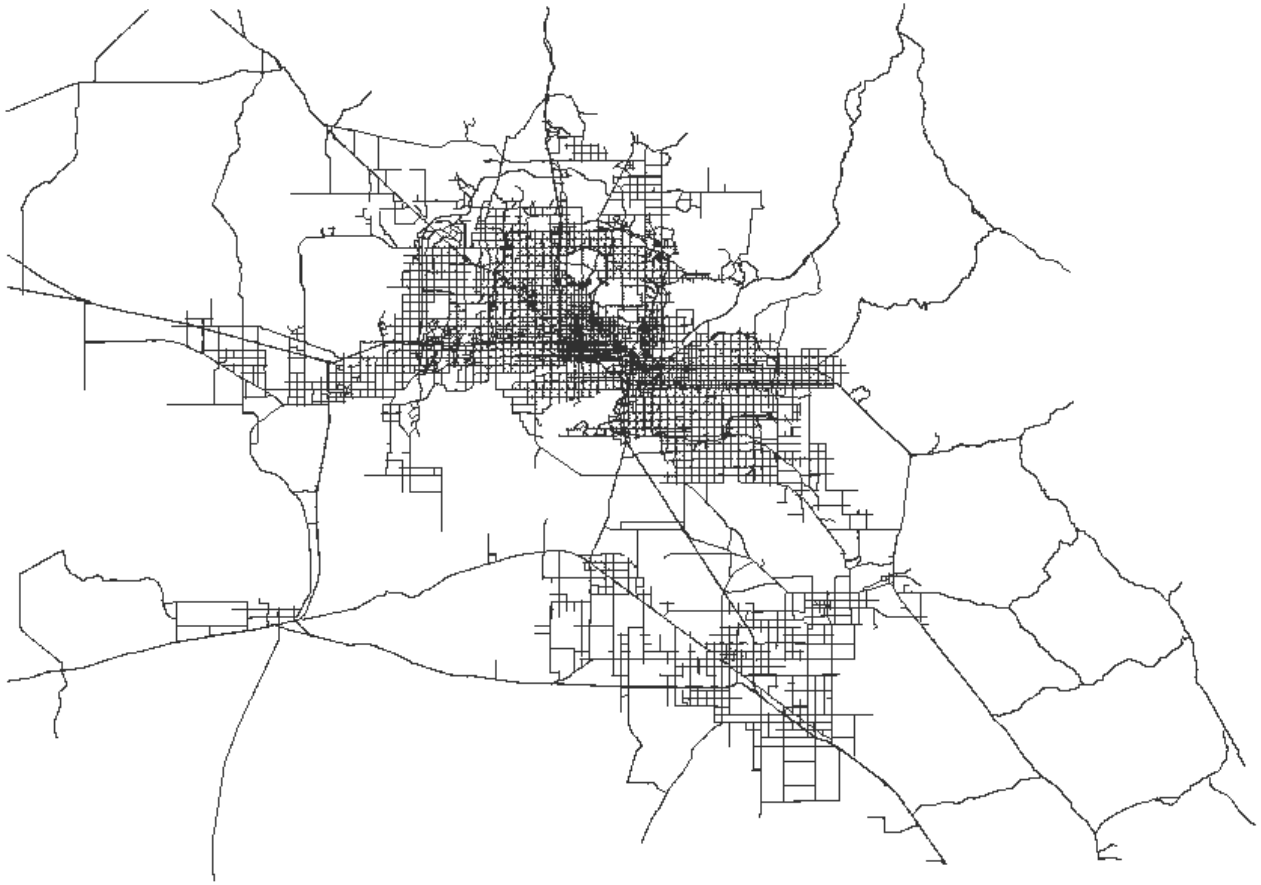
In manner keeping with travel model geography

Model Development

Largely a data assembly, fusion process

Objective

To develop a geometrically accurate road network consistent with planning geography with a complete inventory of traffic counts and signal timings

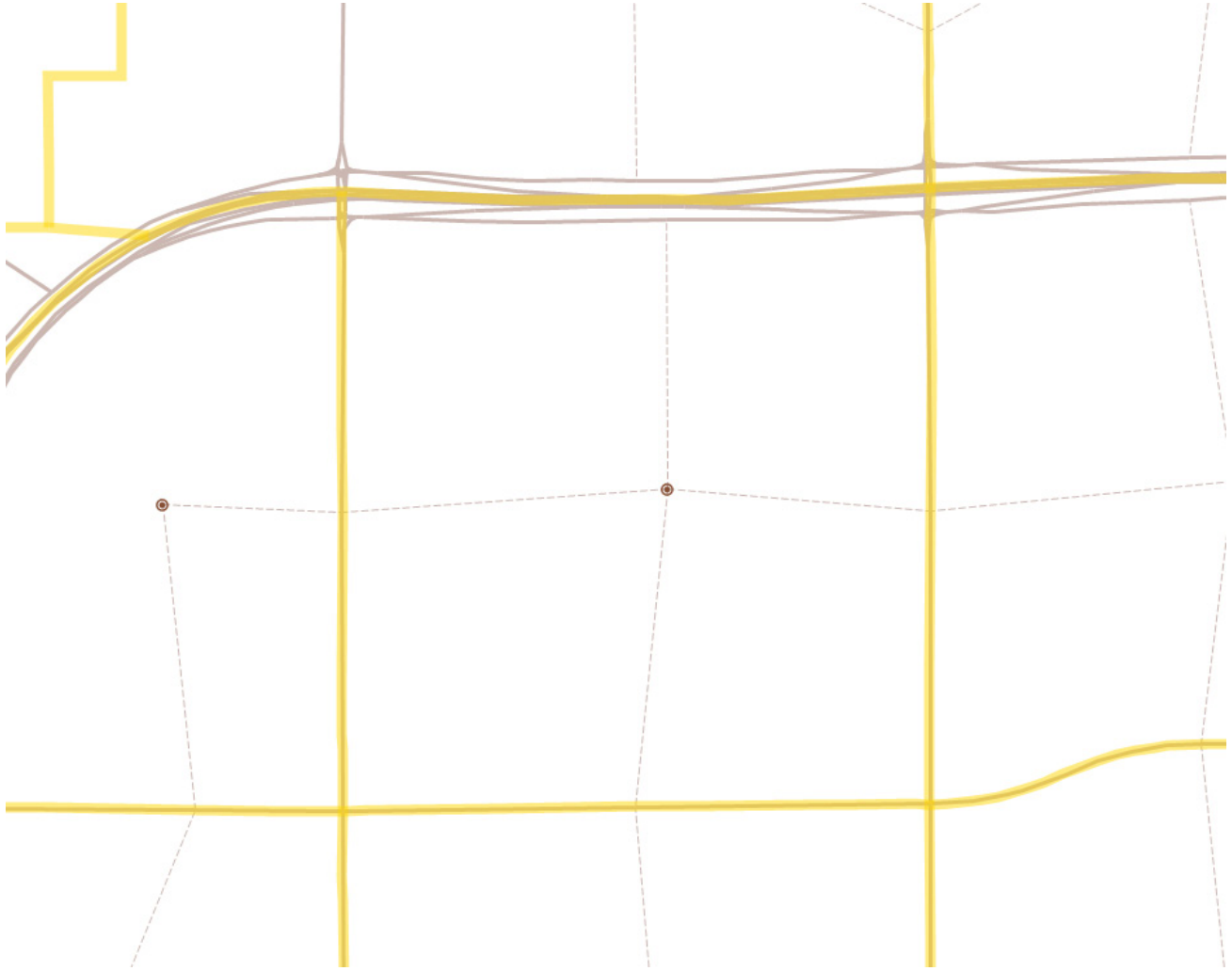


Model Development

Geography, geometry largely drawn by hand on aerial imagery

Model Development

Centroid, centroid connector development favoring midblock, side streets



Model Development

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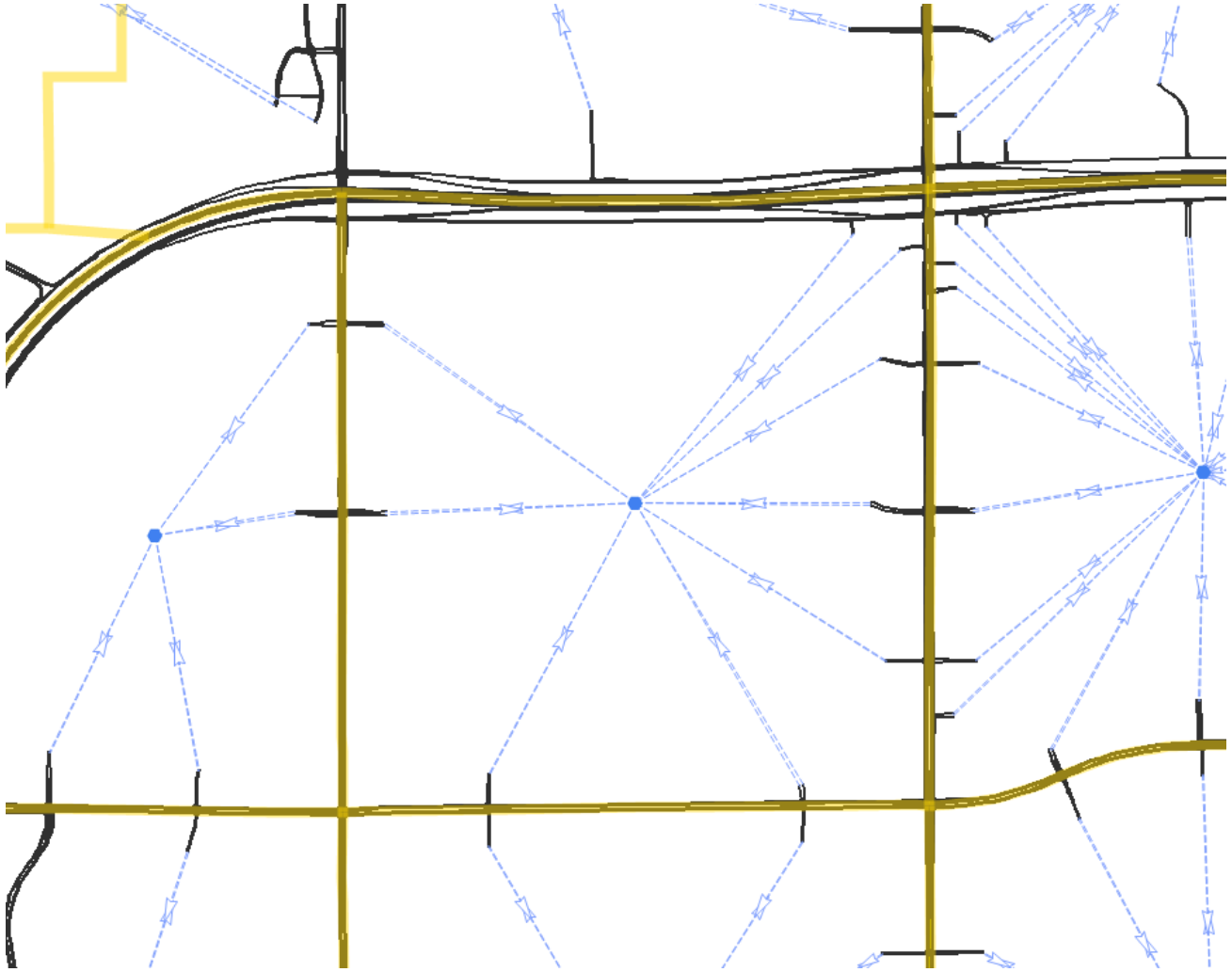
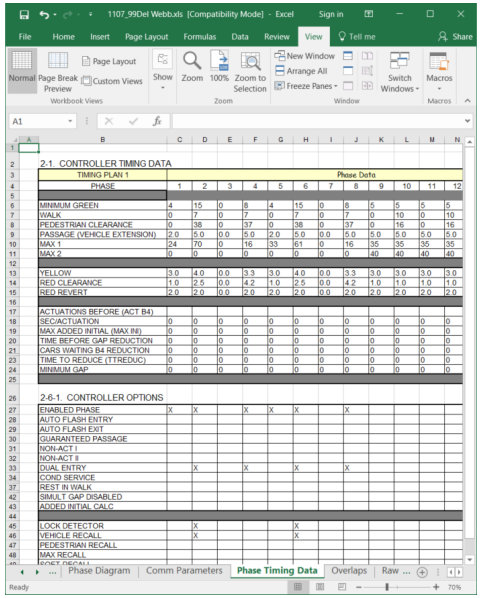
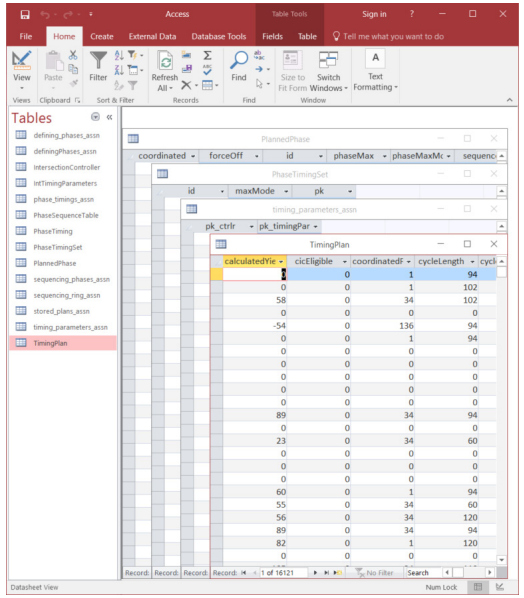
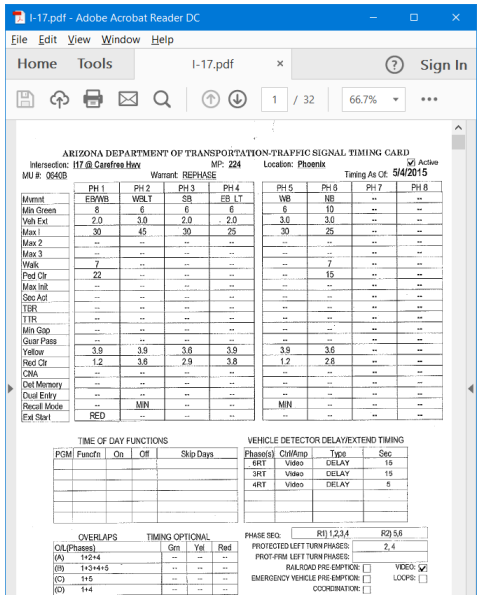


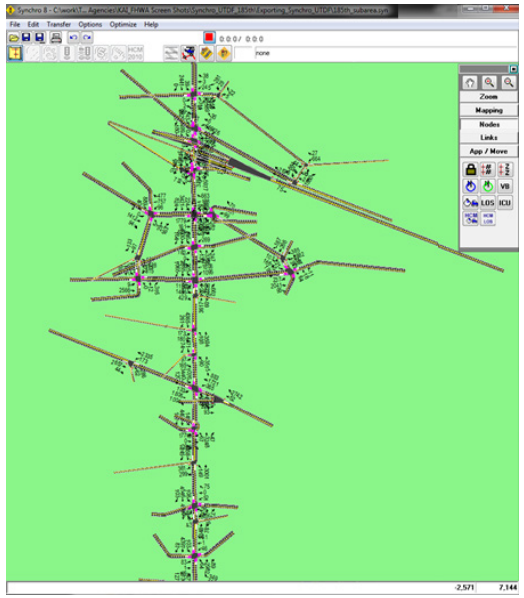
Model Development

Signal timings collected from 30+ agencies in a wide diversity of formats: PDF, Excel, Access, Synchro, more









Model Development:
Room for Improvement

- Detector geometry data not available or easily obtained
- Signal timing data not provided by, available from, some agencies
- Most current signal data in closed, proprietary systems

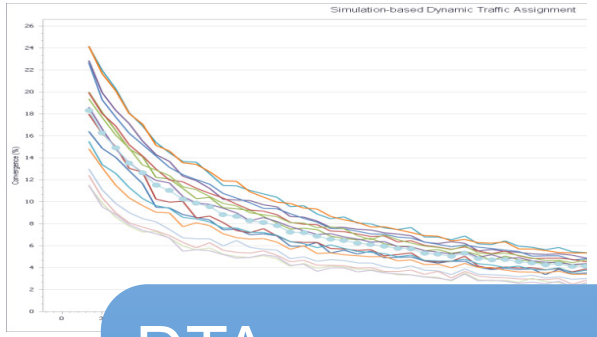
Calibration

Objective

To achieve best possible fit with 15-minute traffic counts

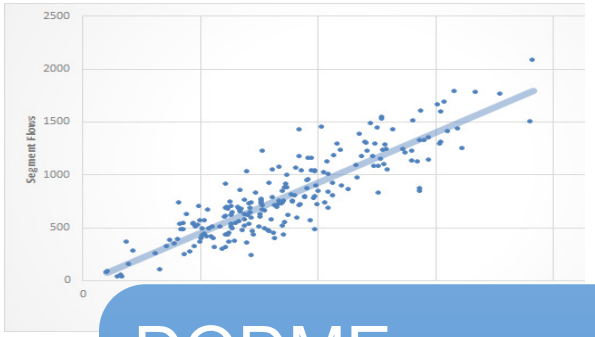
TDM

- Trip-based
- 3-hour AM peak
- 4-hour PM peak
- 2-4 million trips



DTA

- 0.5-sec traffic microsimulation
- Stochastic, dynamic route choice



DODME

- 0.5-sec traffic microsimulation
- Trip list adjustment

Calibration Process

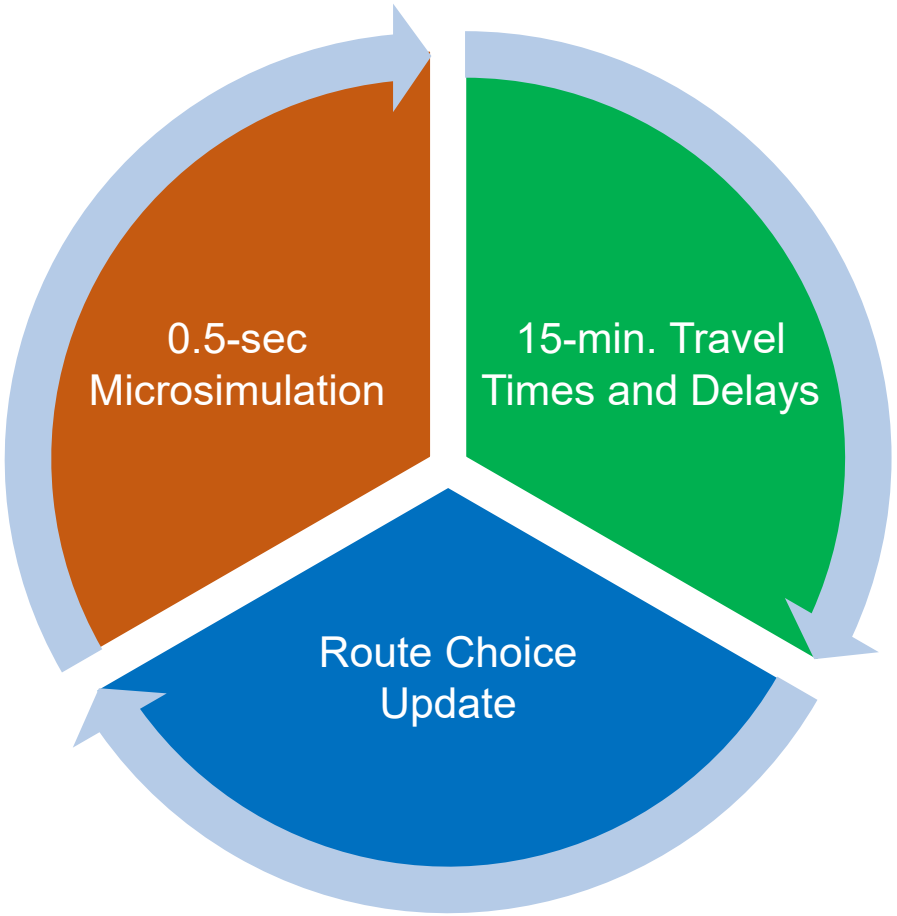
- **TDM**:

  To determine an initial, seed estimation of the O-D trip pattern

Calibration Process

- **DTA**:

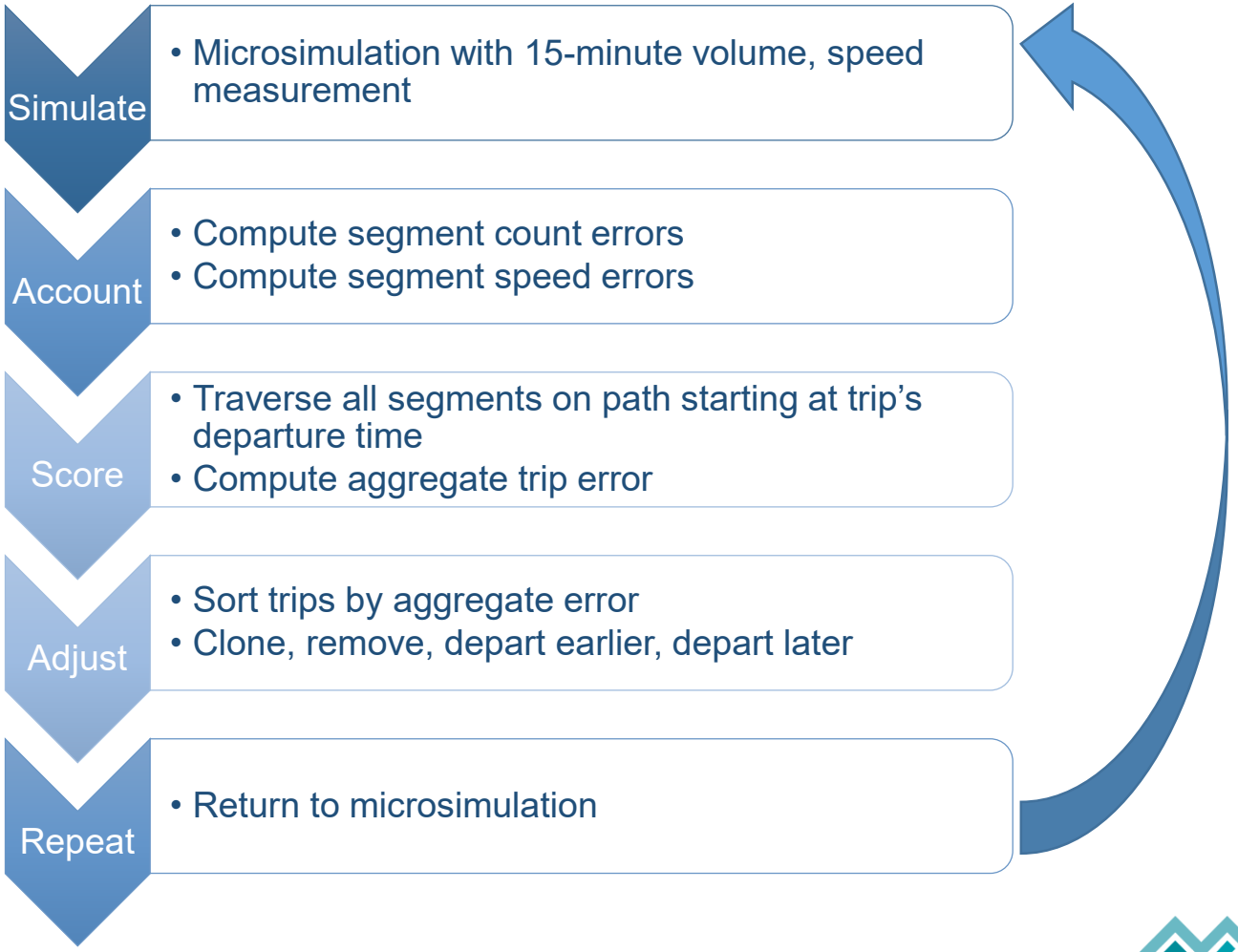
  To estimate typical congested travel times and delays that are key inputs to route choice



Calibration Process

- **D-ODME**:

  To estimate dynamic trip tables that, when simulated, match observed traffic counts

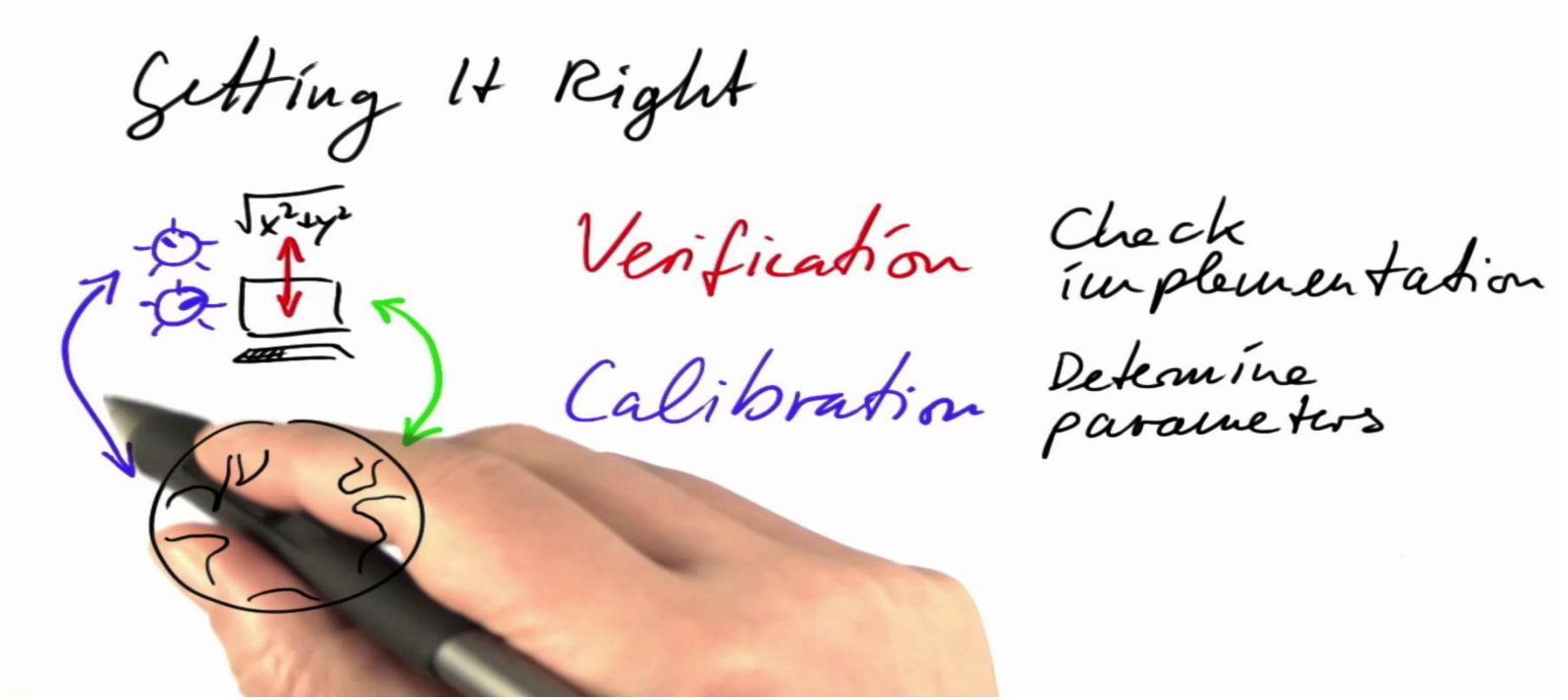


Validation

Objective

To achieve best possible fit with 15-minute NPMRDS speeds and bottlenecks

- Path visualization and audit
- Interactive critical link queries
- Targeted trip table adjustments
- Calibration tools DTA and D-ODME



Validation Process

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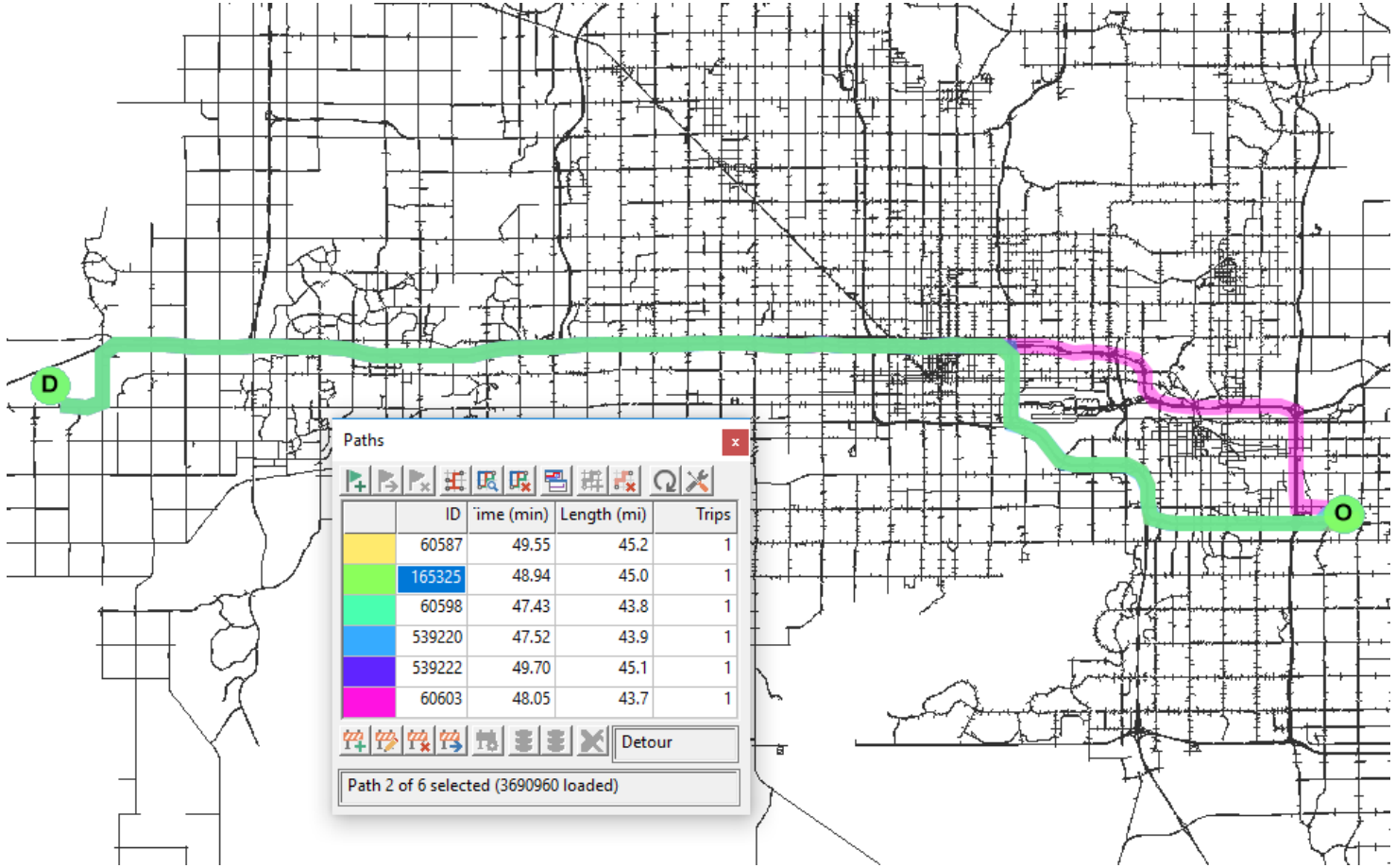

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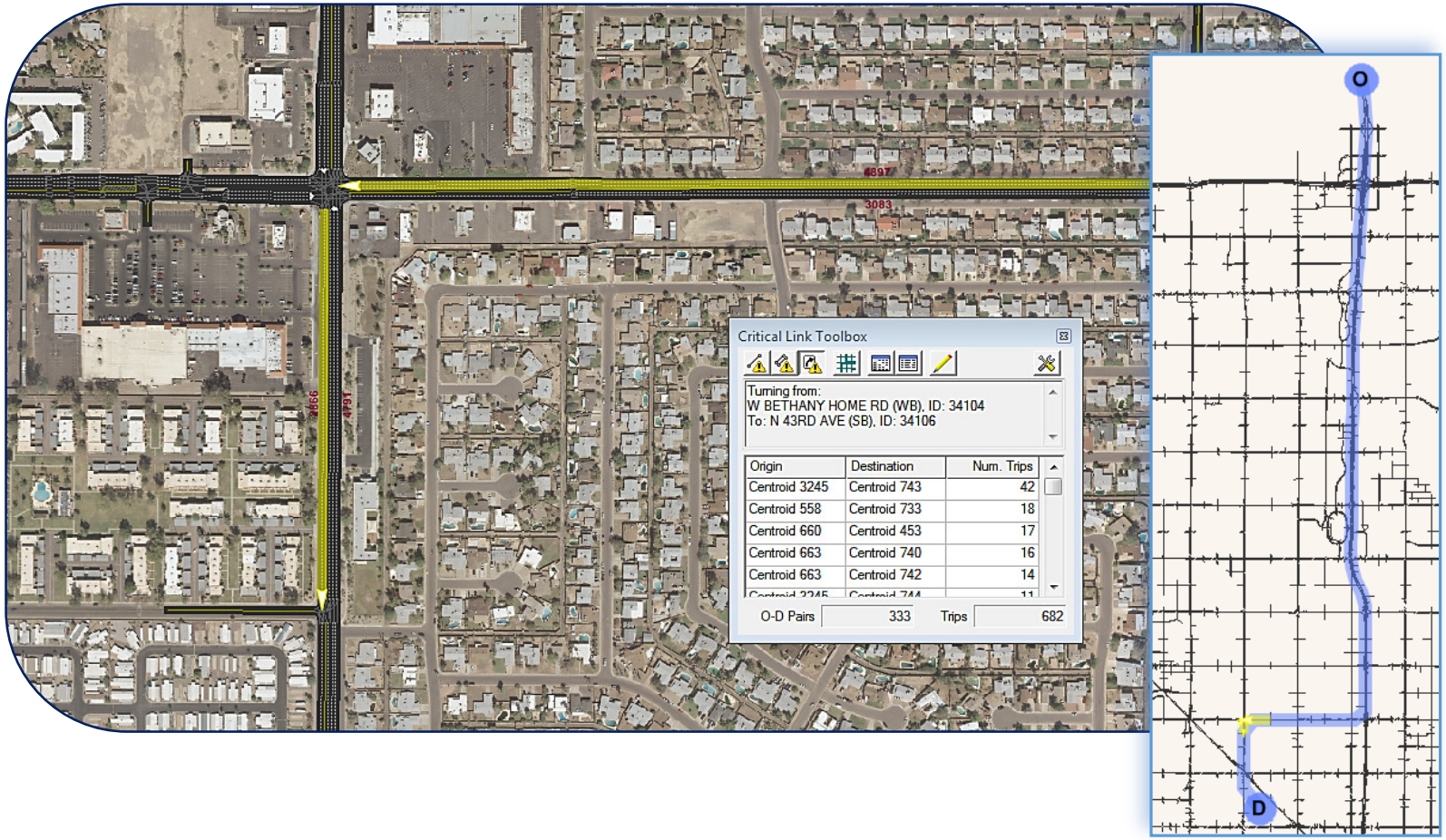

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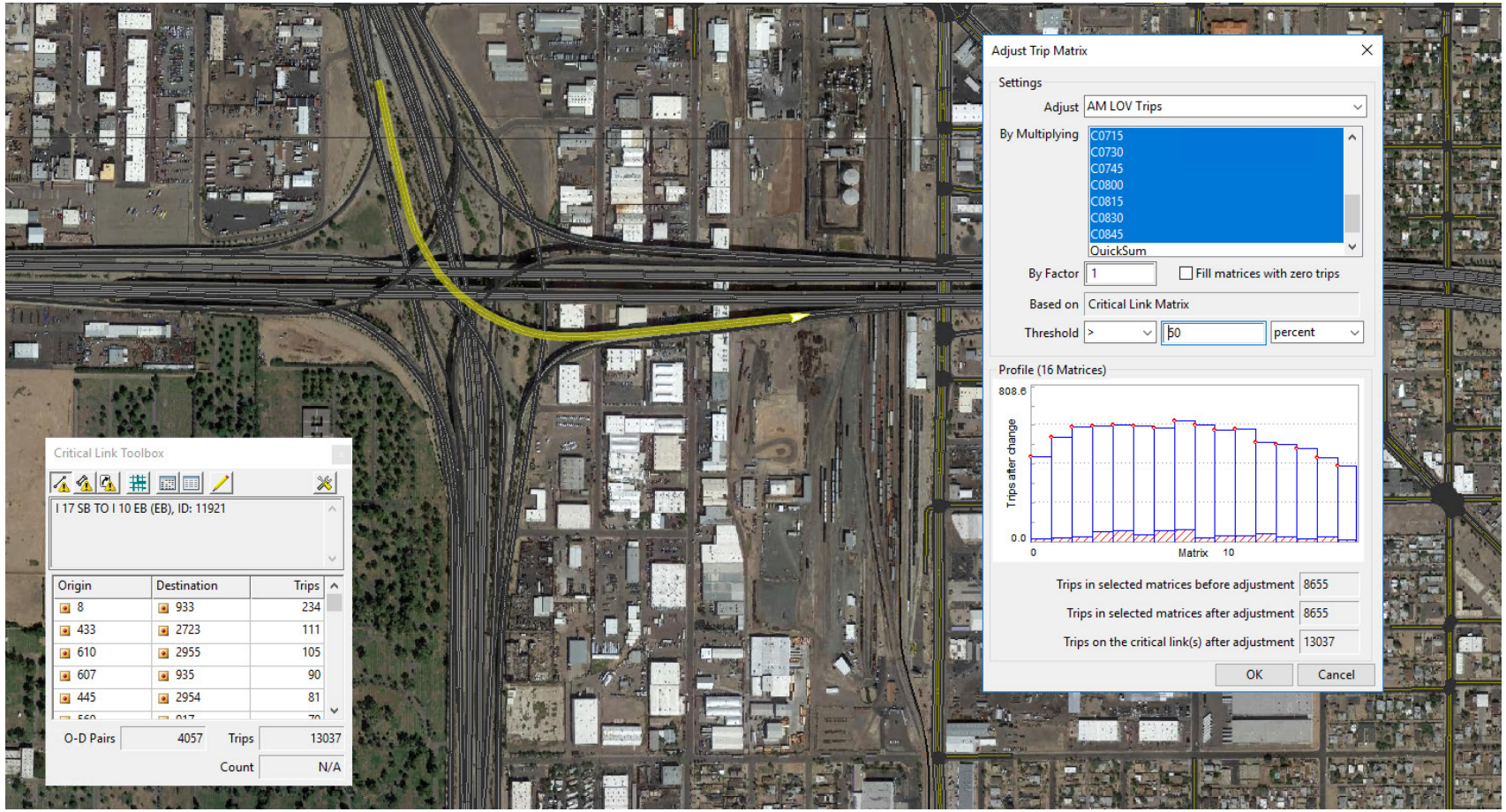

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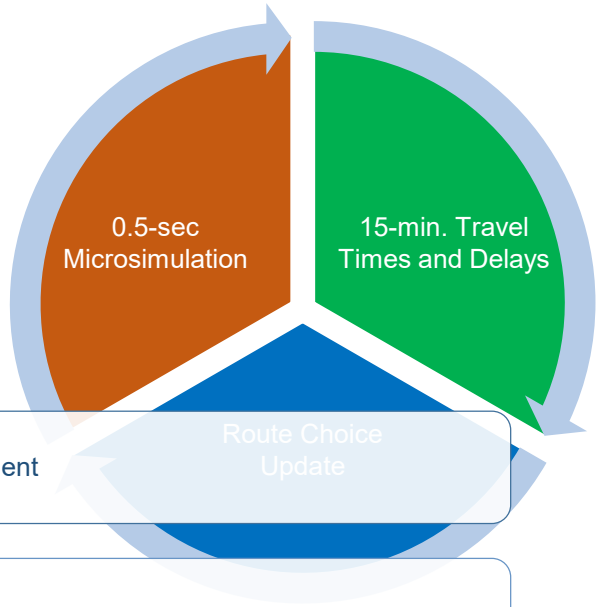


Simulate
- Microsimulation with 15-minute volume, speed measurement

Account
- Compute segment count errors
- Compute segment speed errors

Score
- Traverse all segments on path starting at trip's departure time
- Compute aggregate trip error

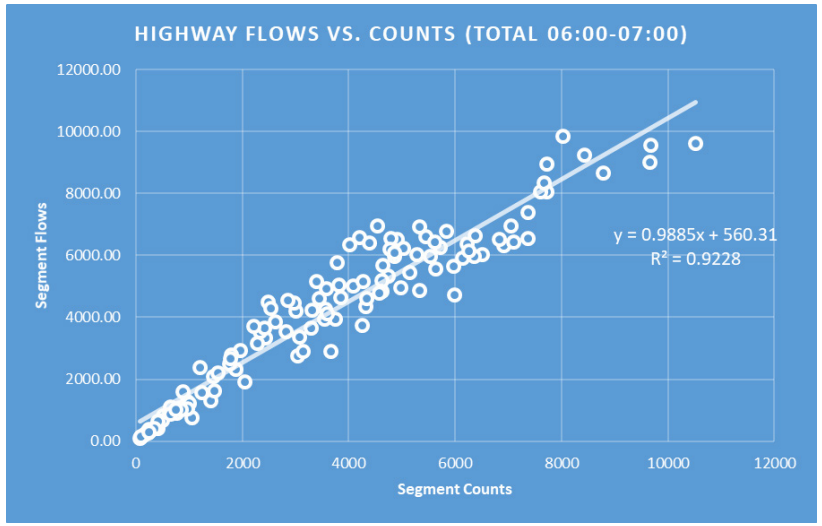
Adjust
- Sort trips by aggregate error
- Clone, remove, depart earlier, depart later

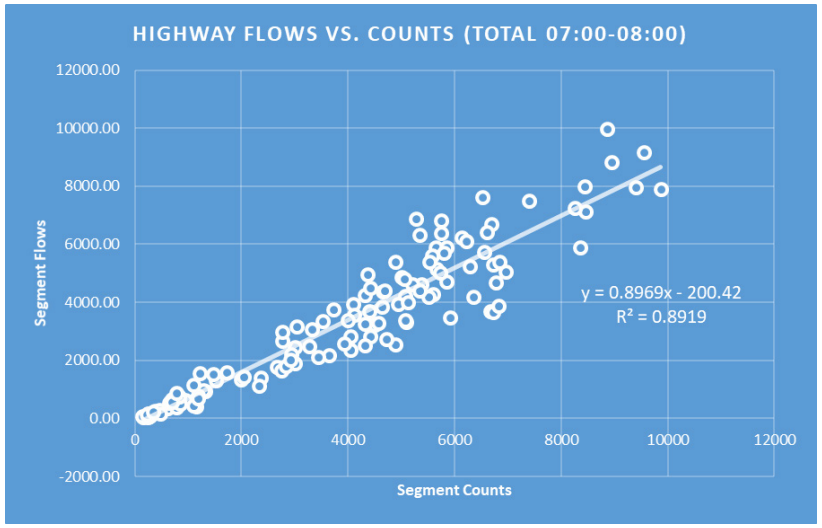
Repeat
- Return to microsimulation

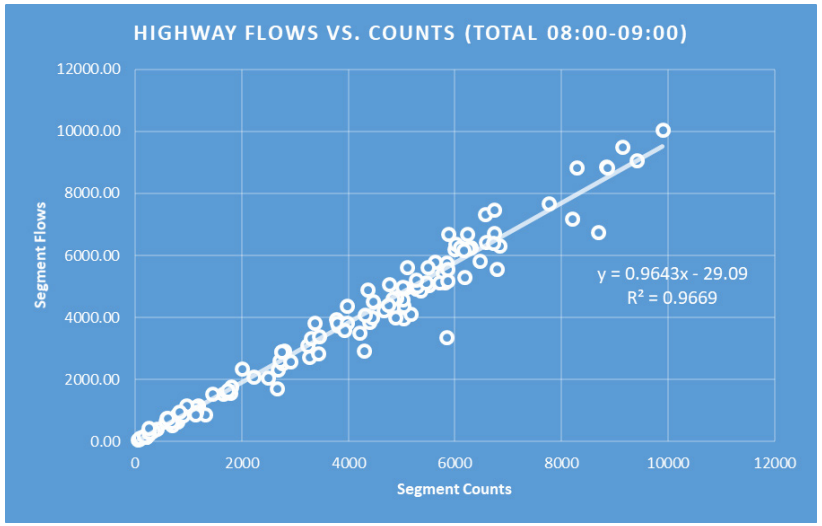
Goodness of Fit: Counts (RMSE)

Period	Interval Beginning	Freeway (N= 209)	Arterial (N= 1941)
		%RMSE	%RMSE
Hour Interval			
AM	6:00	15.6	31.7
	7:00	16.7	29.4
	8:00	19.0	29.1
PM	14:00	14.9	30.2
	15:00	16.0	30.8
	16:00	20.8	33.3
	17:00	24.3	38.1

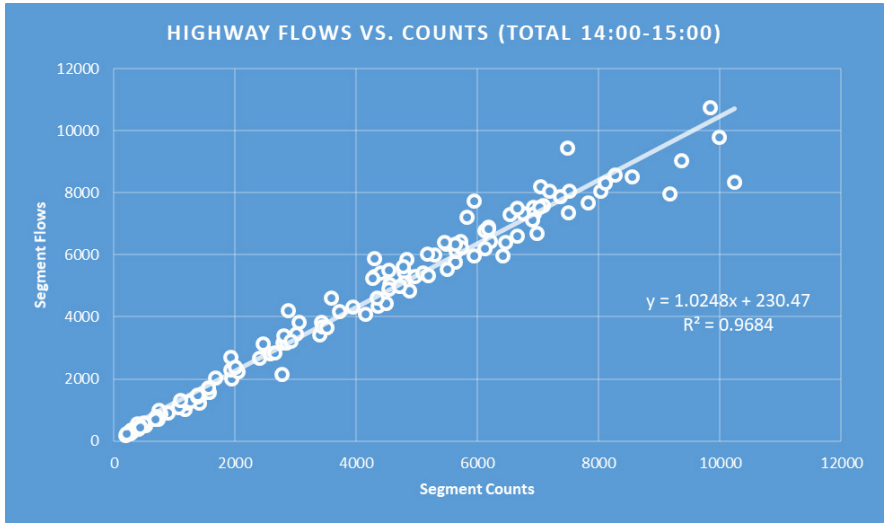
Goodness of Fit: AM Counts (Scatter/R^2)

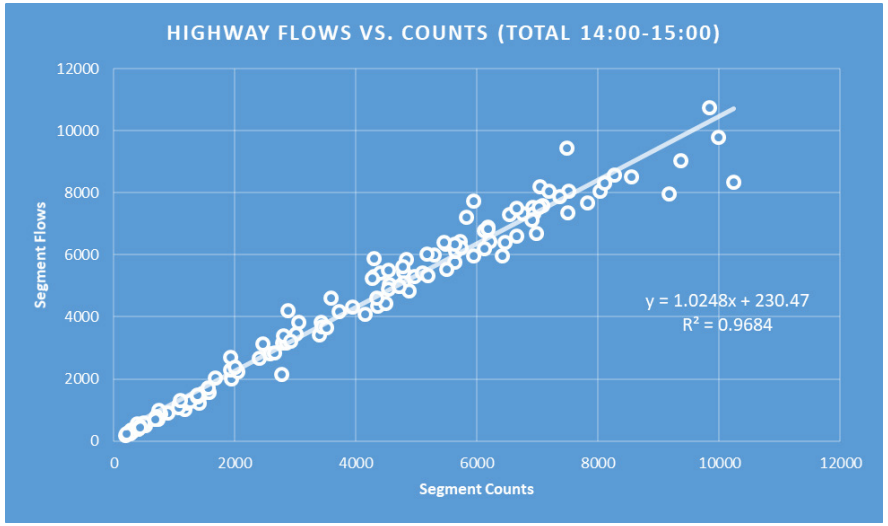


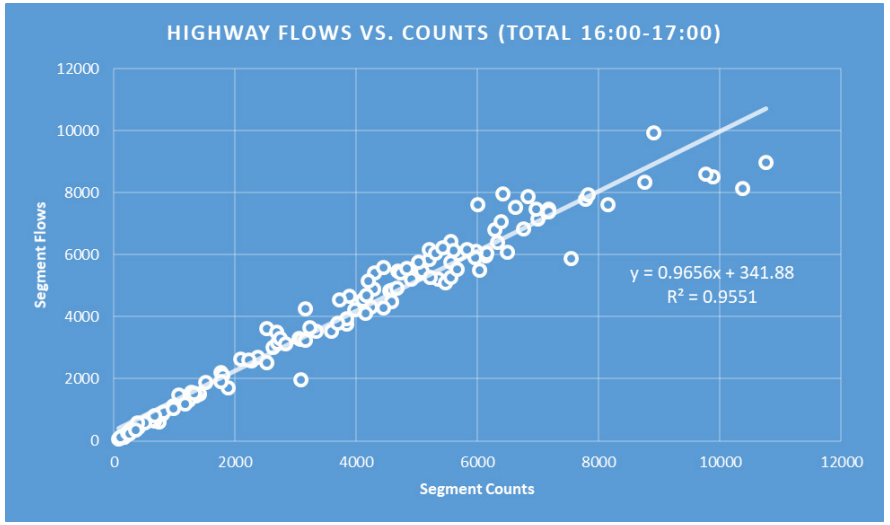


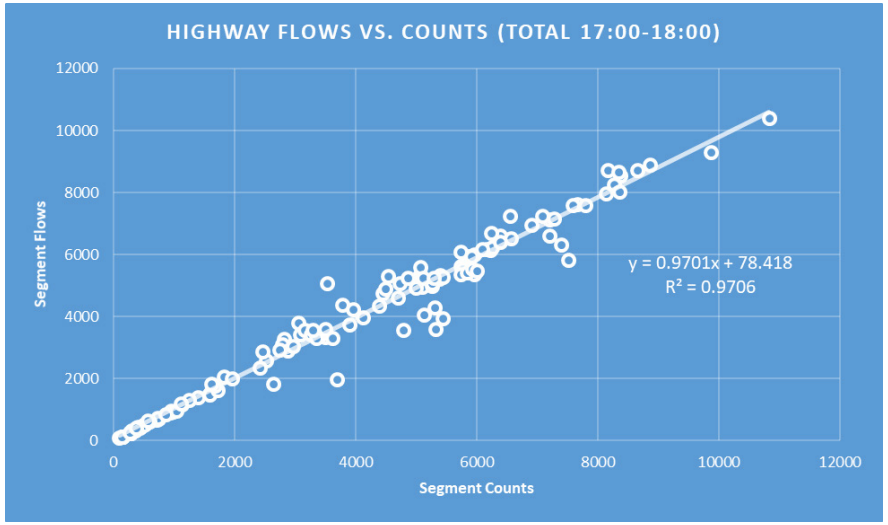


Goodness of Fit: PM Counts (Scatter/R^2)

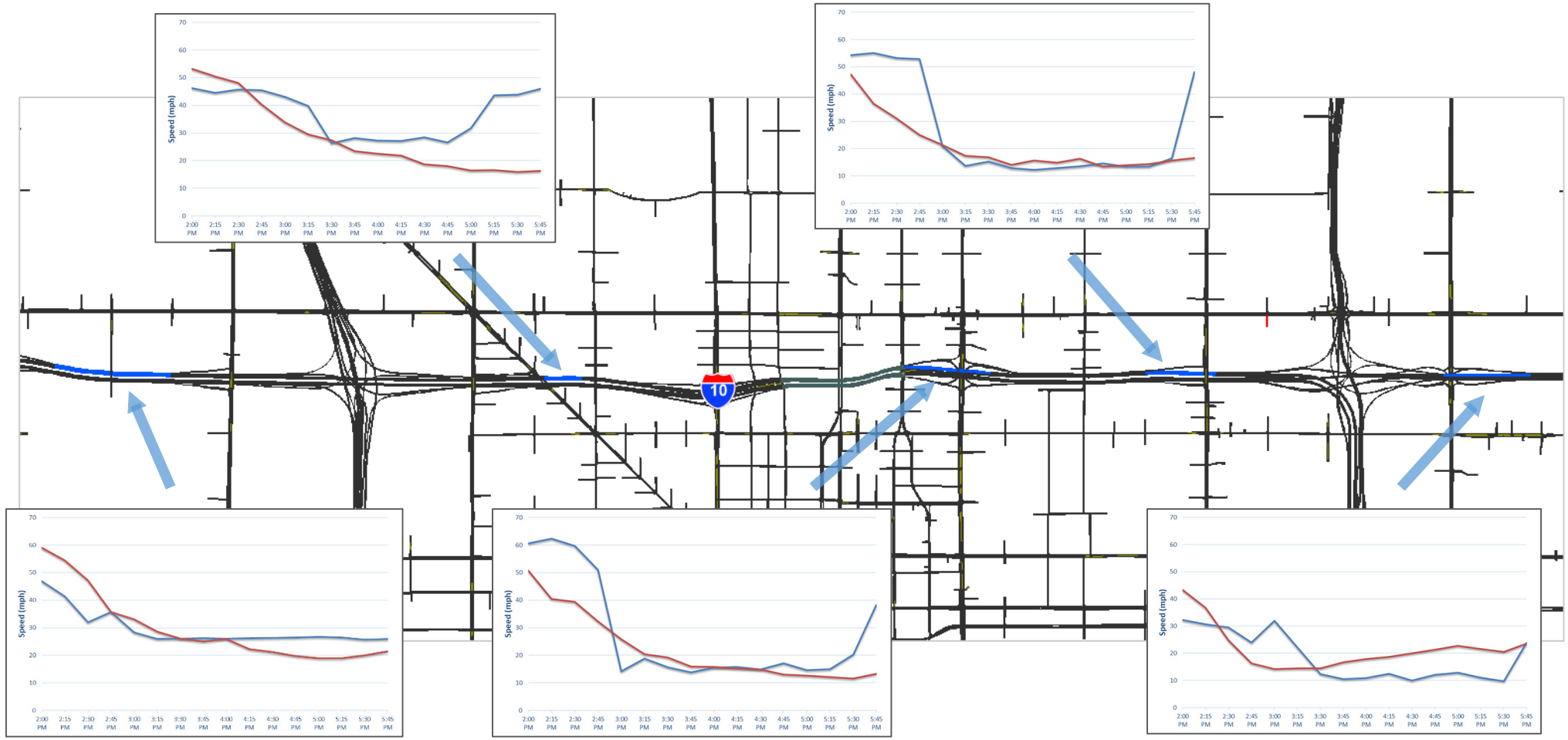








Goodness of Fit: Speeds, Bottlenecks



Calibration, Validation:
Room for Improvement

- Data
  - Observed O-D lacking
  - Counts are not enough
  - Speeds help
  - Ramp counts pivotal but dated
- Methodological
  - More robust count Q/A
  - Speeds as a stronger driver for trip adjustments in DODME

(2) Applications and Visualization

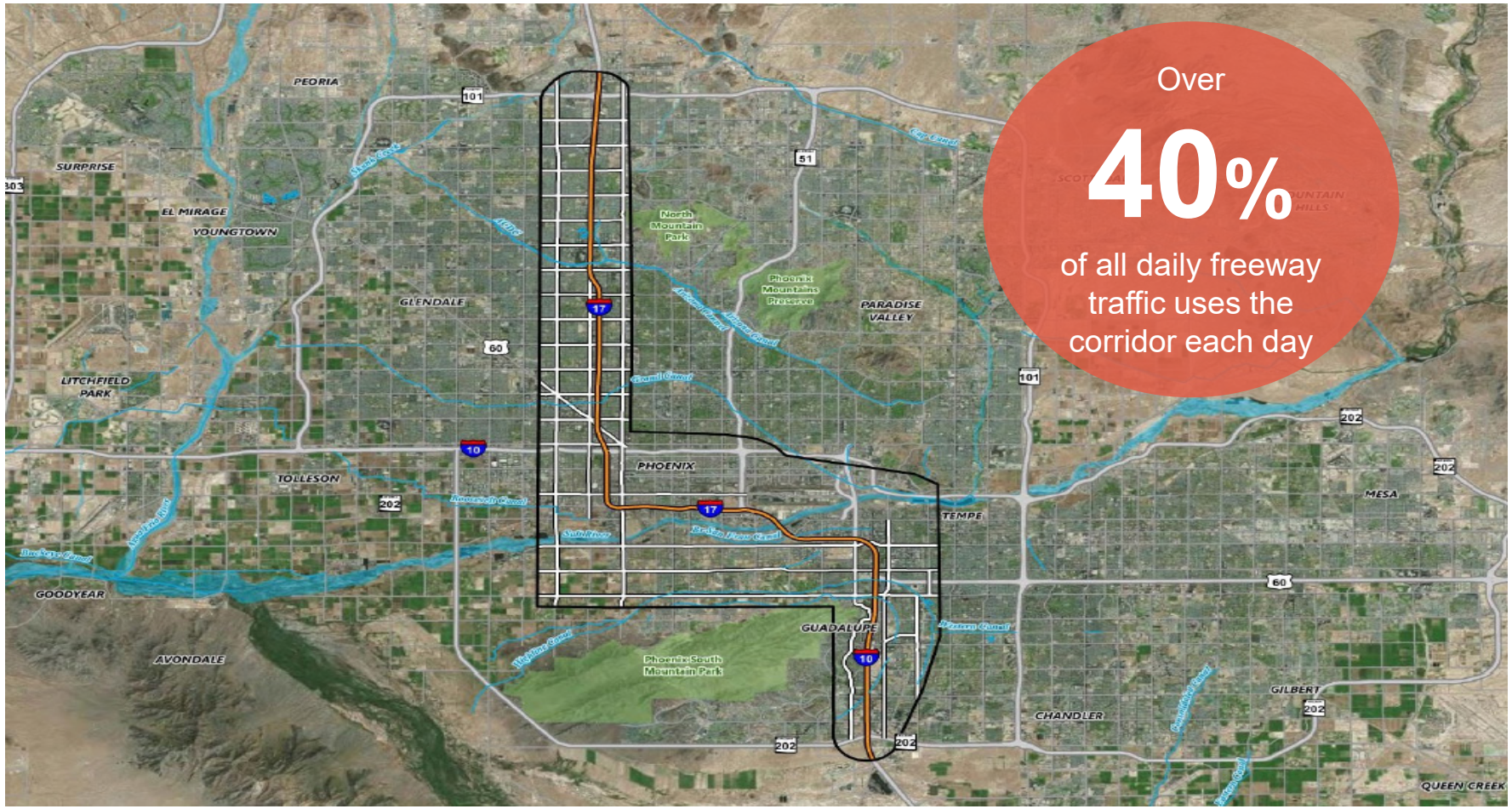
Lan Jiang, Ph.D.

Maricopa Association of Governments

Application:
I-17 Corridor Study

Section I

Spine Study: Background



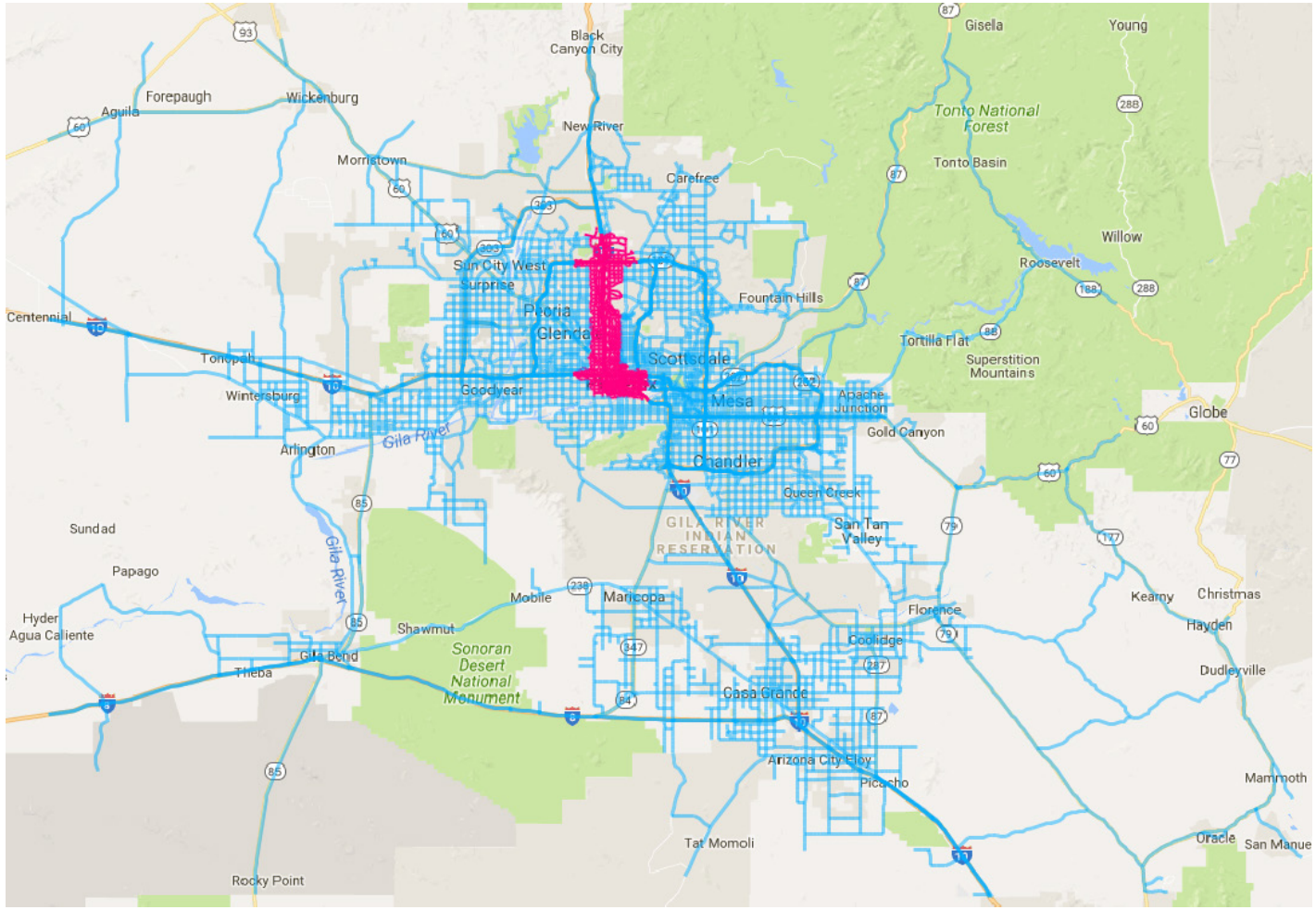
Over

40%

of all daily freeway traffic uses the corridor each day

Reference: http://spine.azmag.gov

Spine Network



MAG Regional Network

Spine Network

Goodness of Fit: Counts (RMSE)

Period	Facility	Hour Starting	%RMSE
AM	Freeway	6:00 AM	8.78%
		7:00 AM	7.46%
		8:00 AM	10.34%
	Arterial	6:00 AM	31.10%
		7:00 AM	23.74%
		8:00 AM	26.87%
PM	Freeway	2:00 PM	8.10%
		3:00 PM	9.20%
		4:00 PM	14.37%
		5:00 PM	19.55%
	Arterial	2:00 PM	23.82%
		3:00 PM	24.55%
		4:00 PM	27.50%
		5:00 PM	30.26%

Notes:
Arterial Counts: 216
Freeway Counts: 32

Vehicle Trajectory Data in Validation

Data Collection

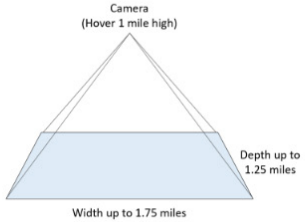
2 Helicopters

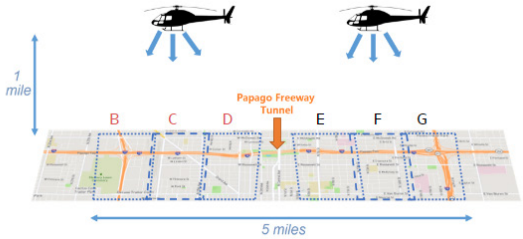
6 Cameras

21 M pixels per image

1 Frame per second

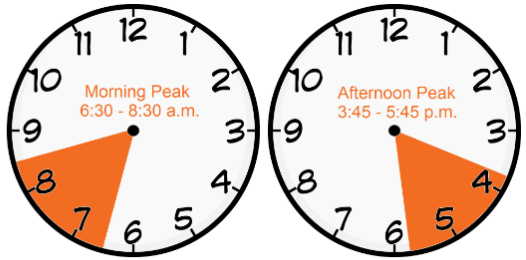
2-Hour survey per peak period

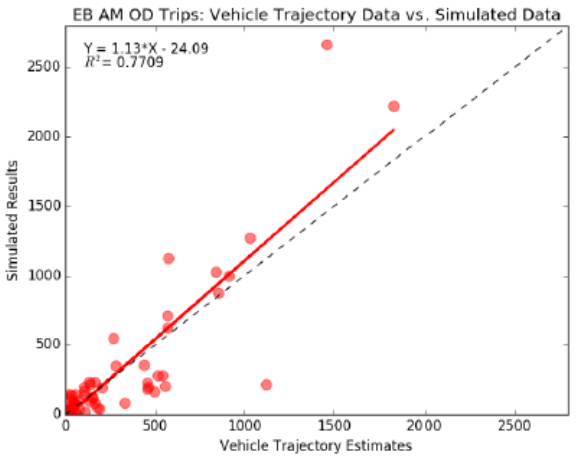


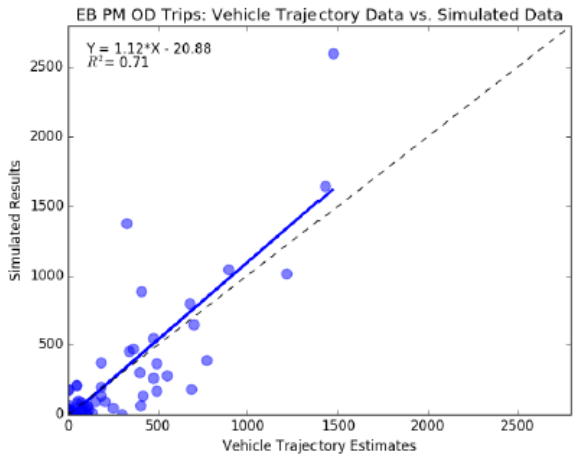


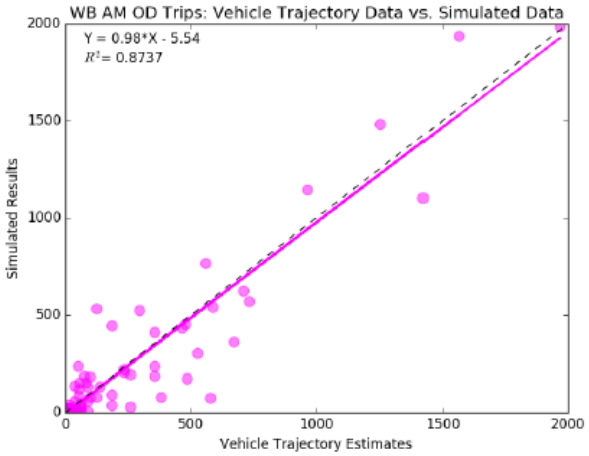
2 days were selected based on historical traffic data

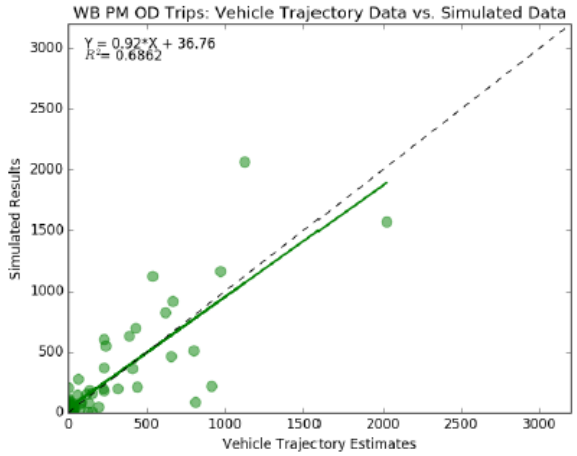
2 peak periods each day to show the development, evolution and discharge of recurring congestion at bottlenecks.





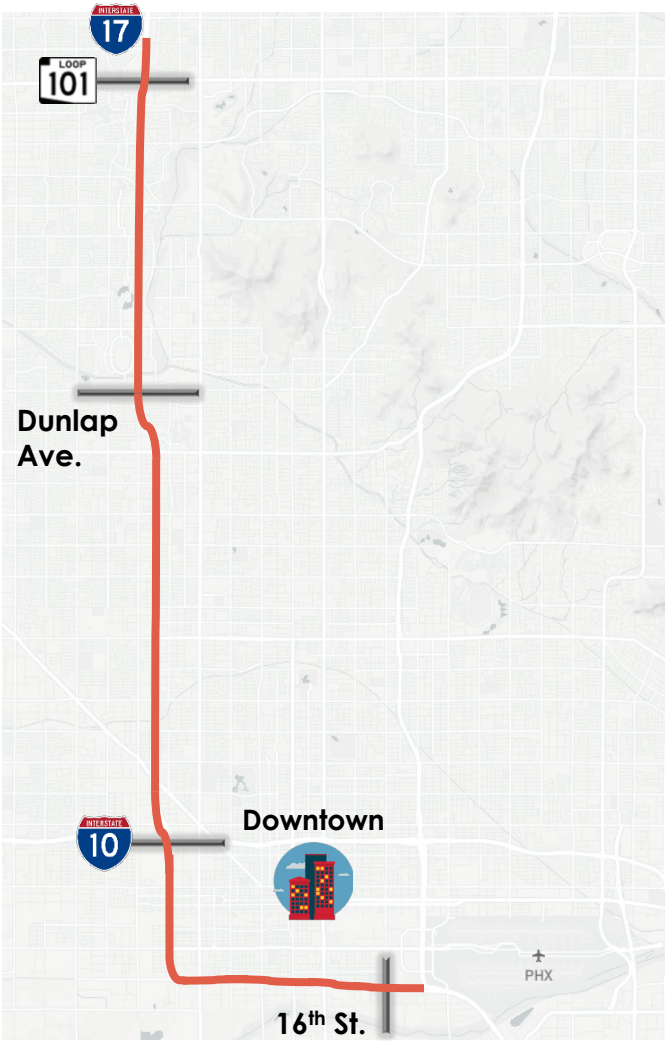






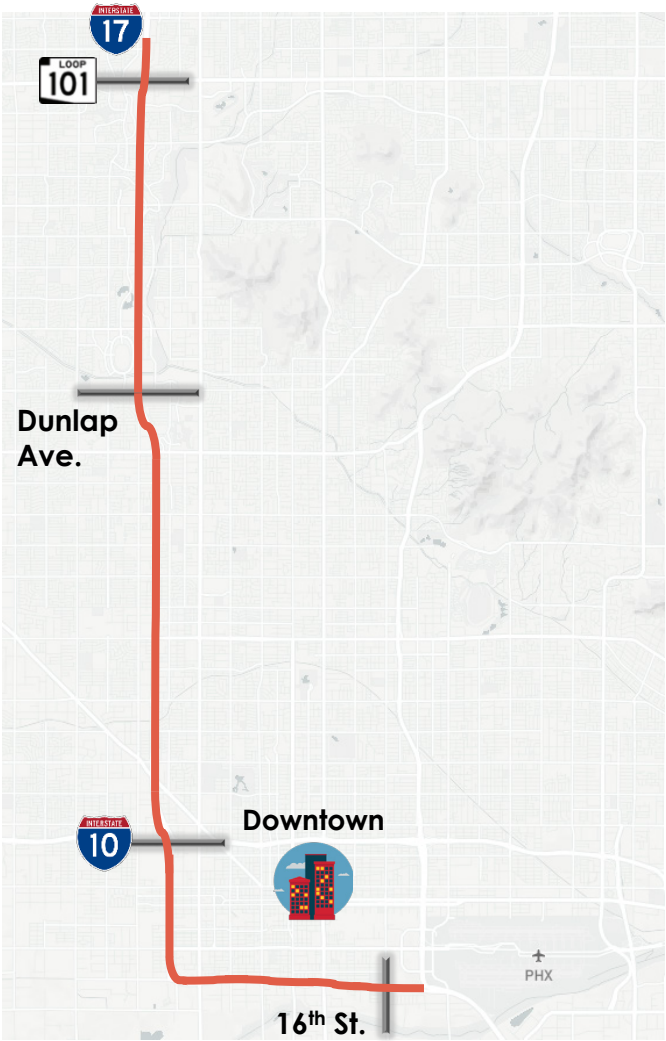
References: MAG Bottleneck Study TMIP Webinar on Oct. 18, 2017 & http://bottleneckstudy.azmag.gov

Alternative Scenario



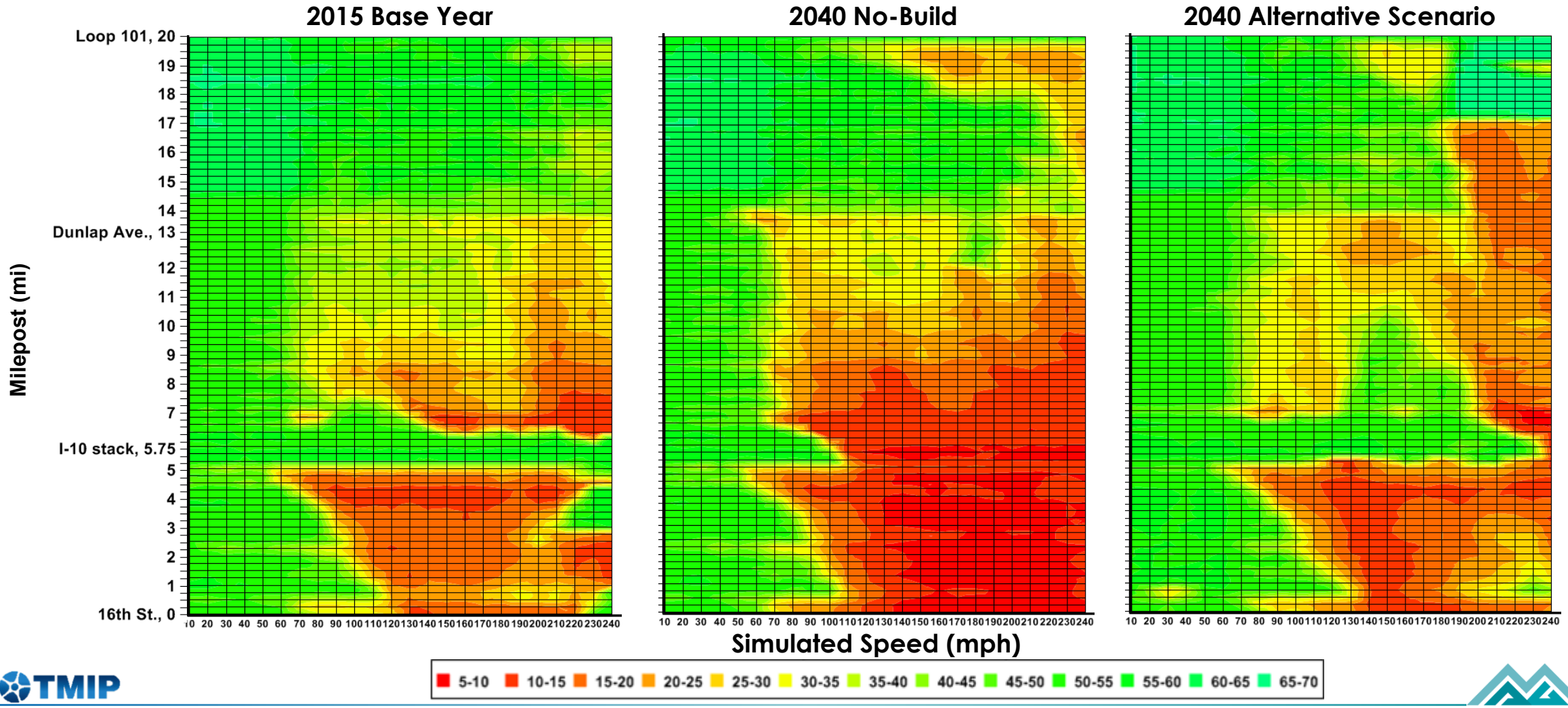
Existing Infrastructure:
<u>ONE</u> HOV Lane each direction on I-17

Alternative Scenario

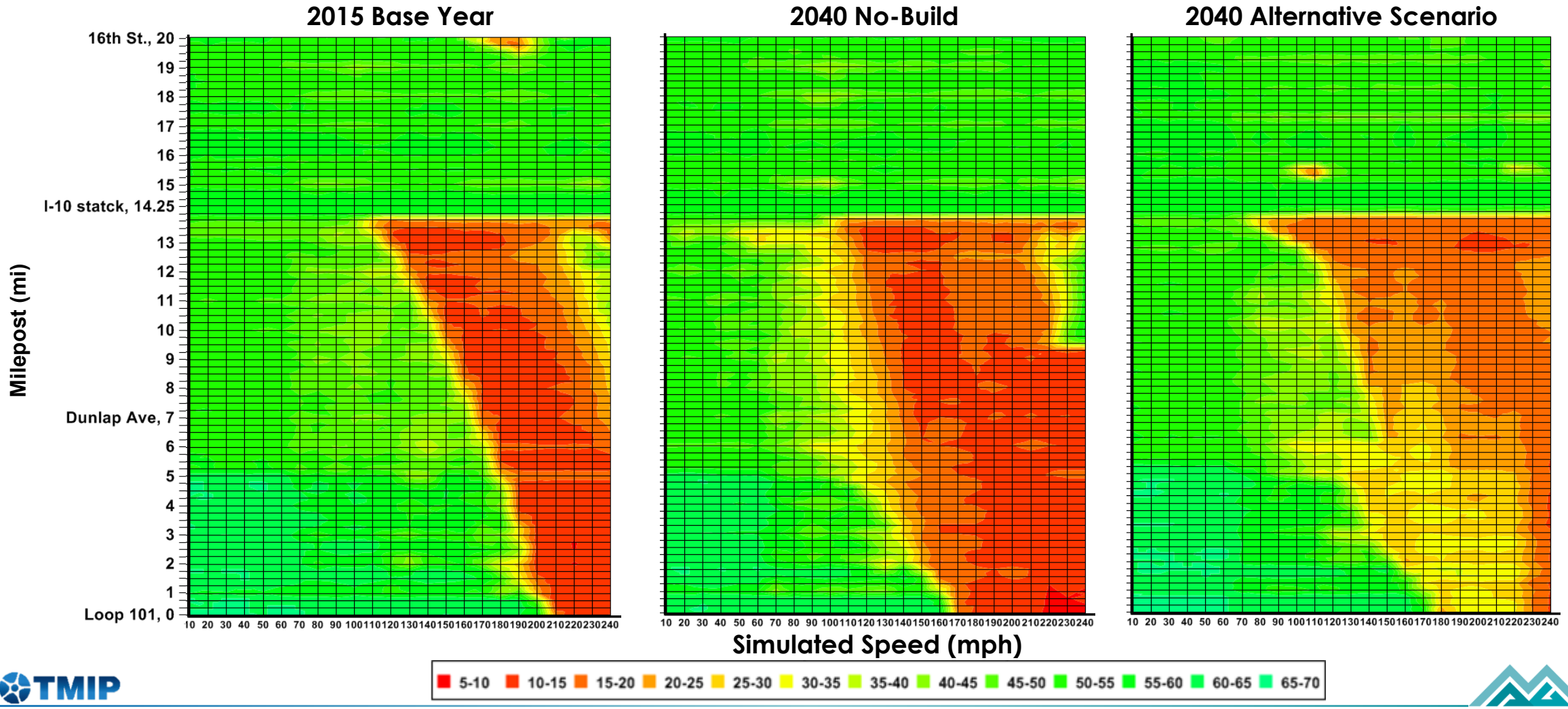


Alternative Scenario:
<u>TWO</u> HOV Lane each direction on I-17

Simulated Speed Contour Plot: PM NB



Simulated Speed Contour Plot: PM SB



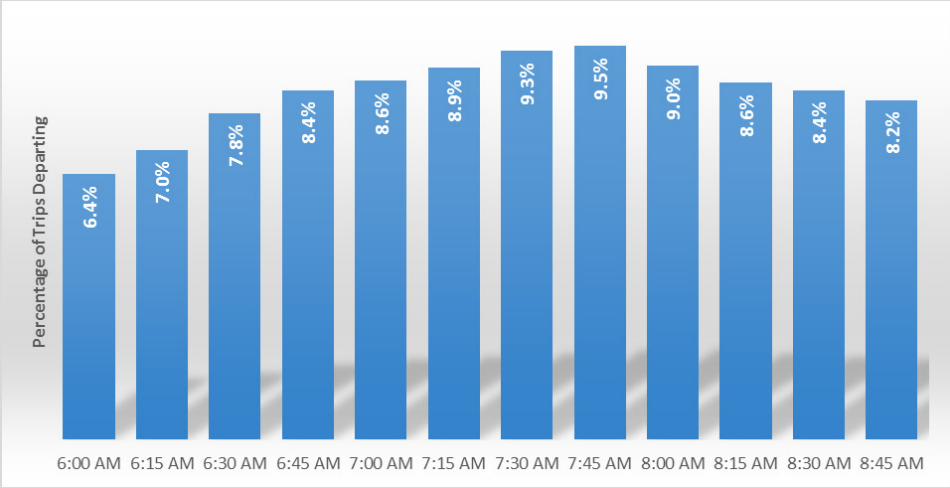
Visualization:

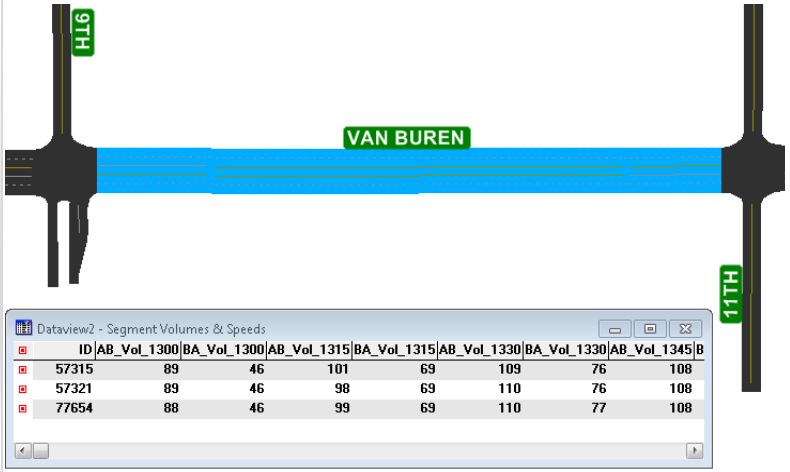
Interactive Maps

Section II

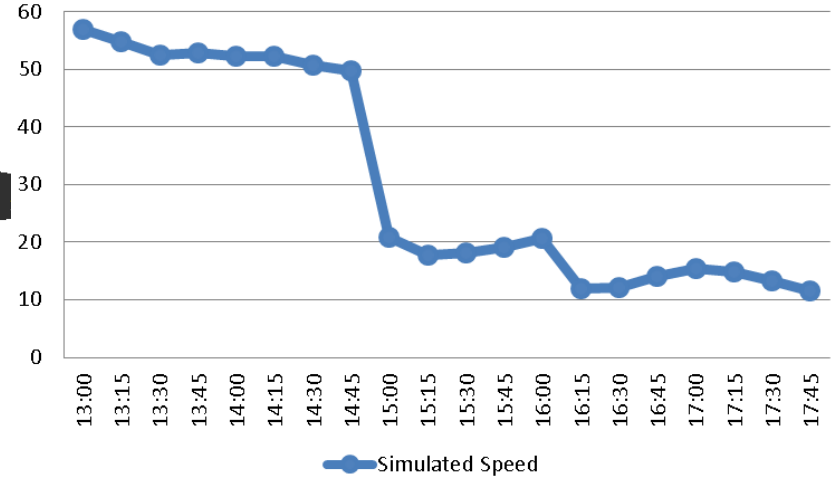
Show Me The Data: Challenges

- **'Big' Data Sets**
  - Spatial & temporal data sets at regional level
- **Usability and Limitations**
  - Software-specific data display features
  - Limitations of video clips





ID	AB_Vol_1300	BA_Vol_1300	AB_Vol_1315	BA_Vol_1315	AB_Vol_1330	BA_Vol_1330	AB_Vol_1345	B
57315	89	46	101	69	109	76	108	
57321	89	46	98	69	110	76	108	
77654	88	46	99	69	110	77	108	



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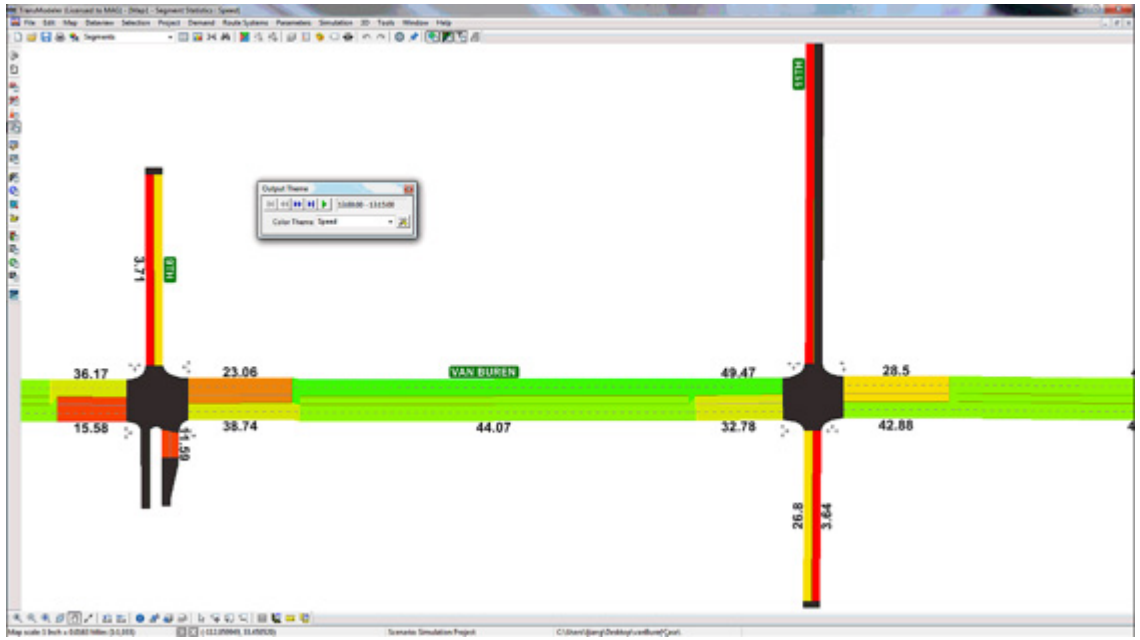

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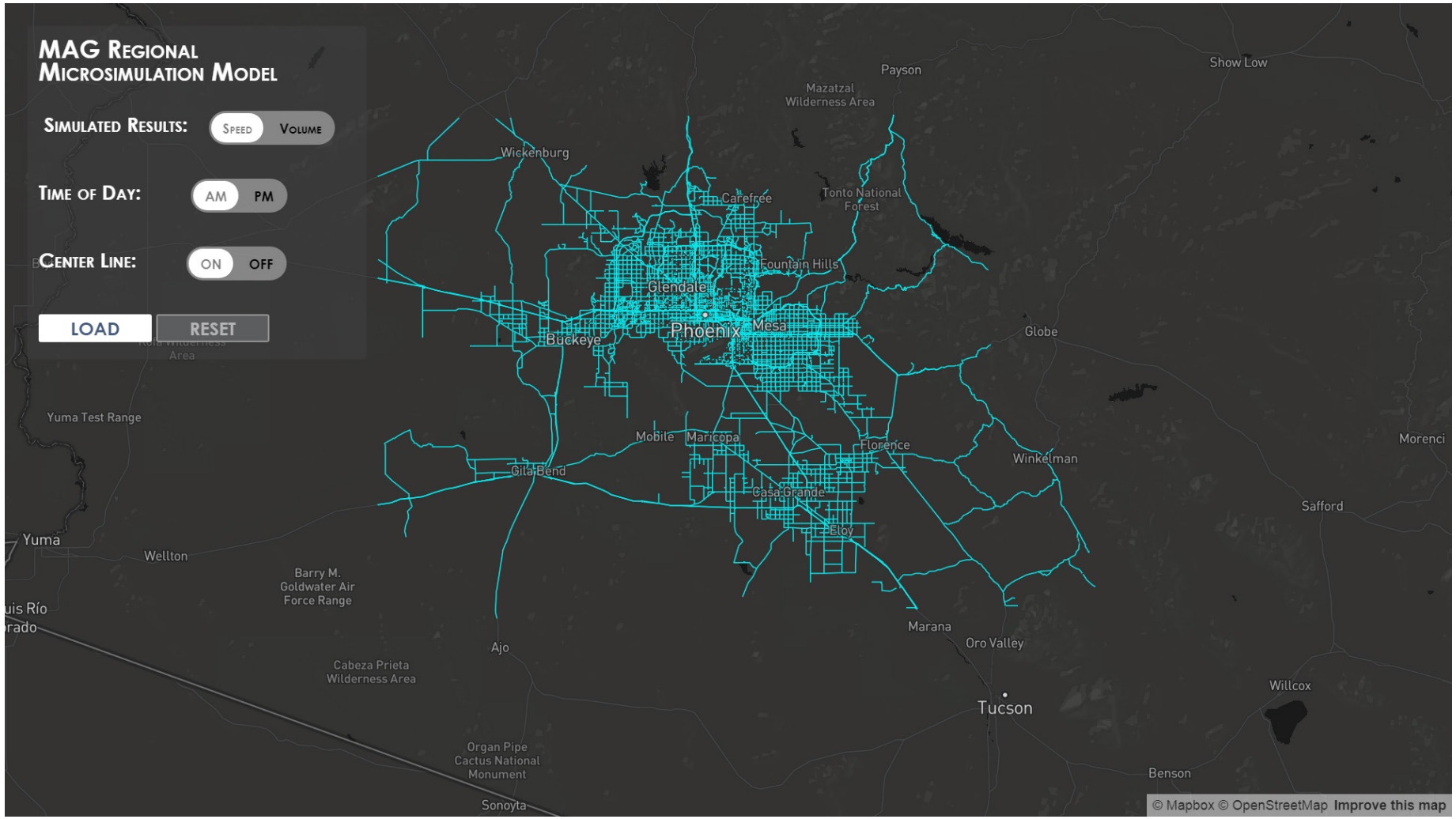
Interactive Maps: Features

- **Ease of Use**
  - Intuitive control panel
- **Fast and Lightweight**
  - Smooth data loading and visualization
- **Easy Share**
  - Map and data can be viewed in most web browsers
- **Customized Tool**
  - Flexible in map design and control using HTML & JAVASCRIPT

Interactive Map Interface



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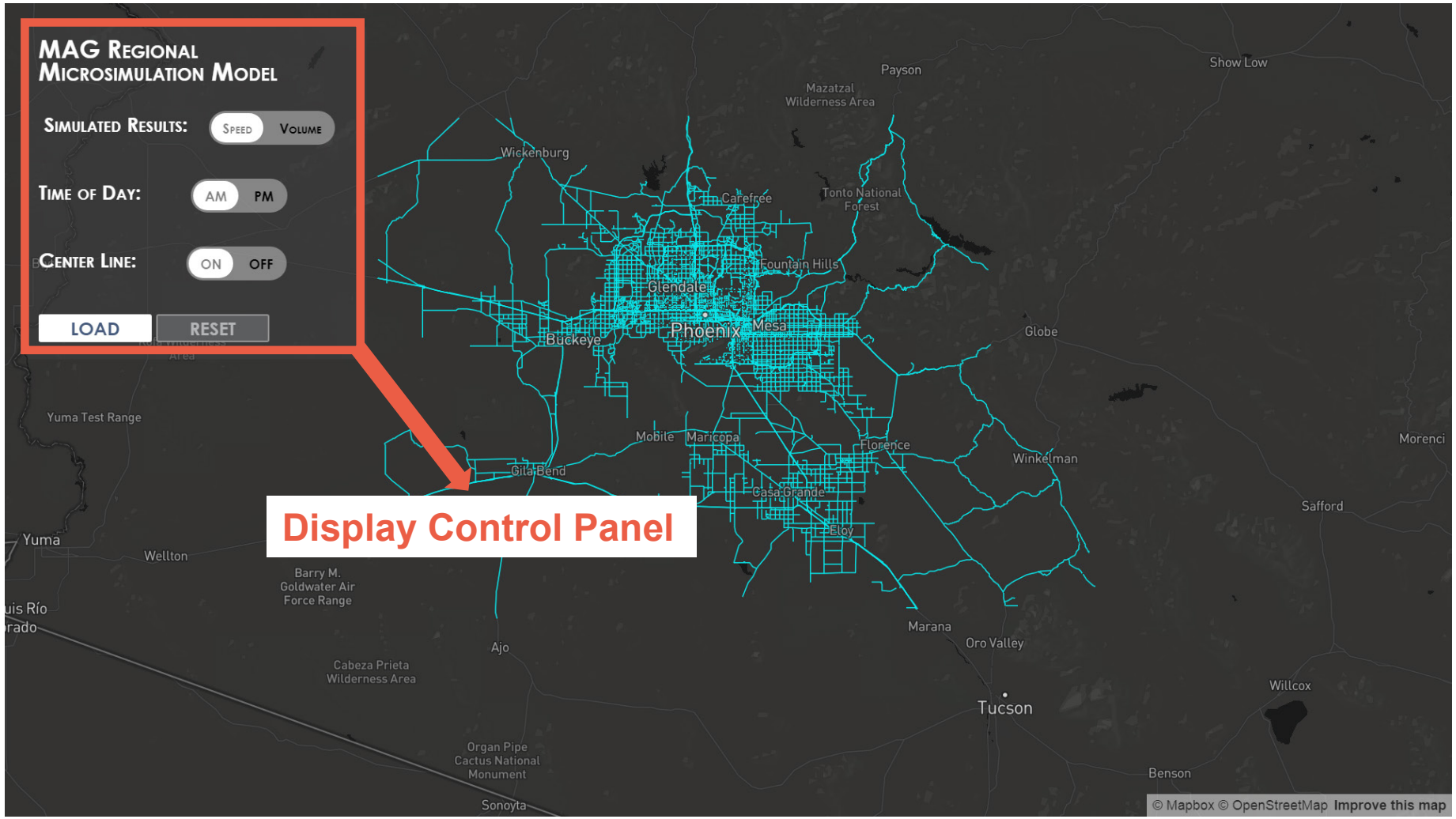
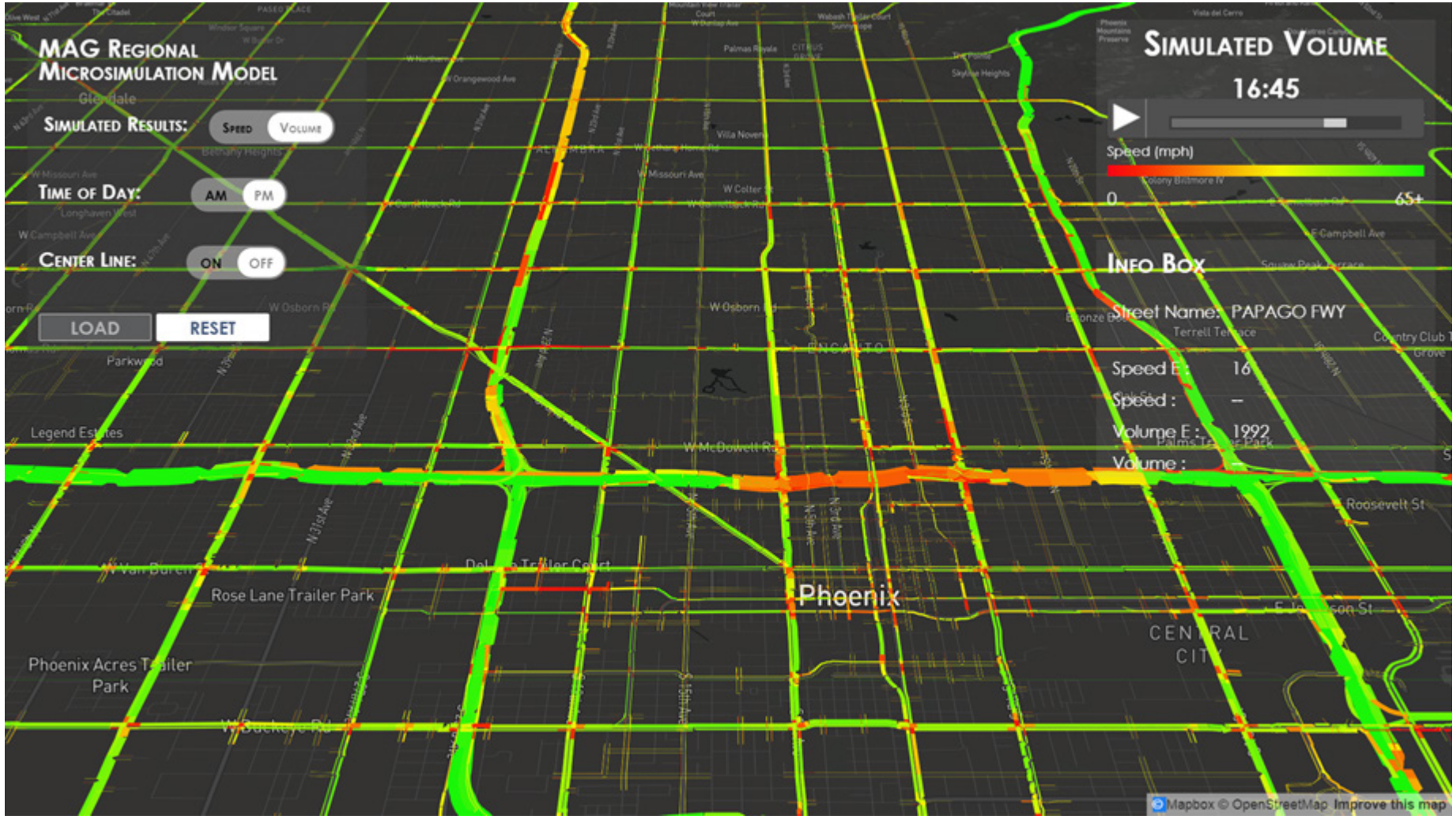
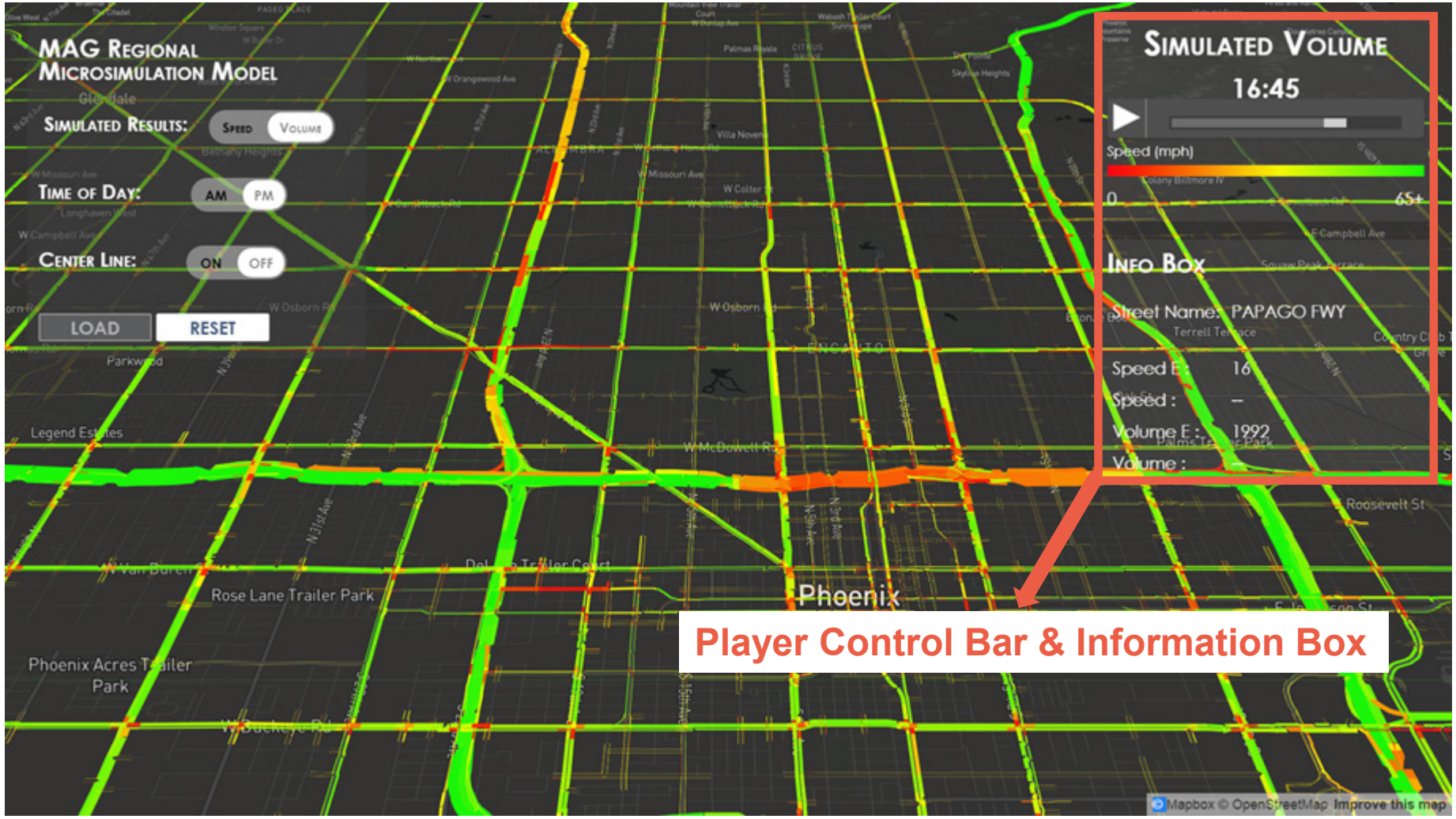


Interactive Map Interface



Interactive Map Interface

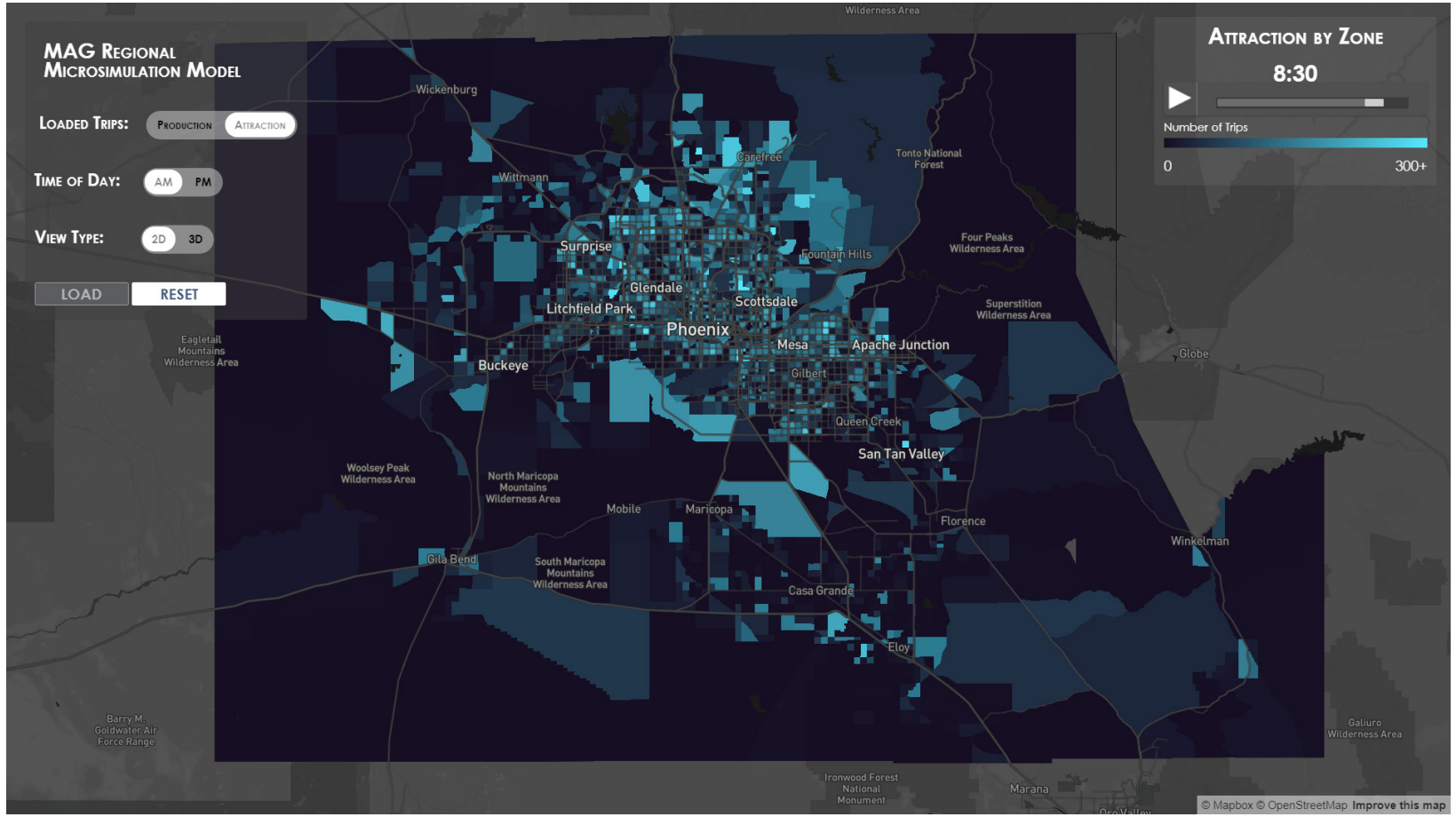


Interactive Map Interface

- Demo: Clip 2 – MAG Microsimulation.mp4

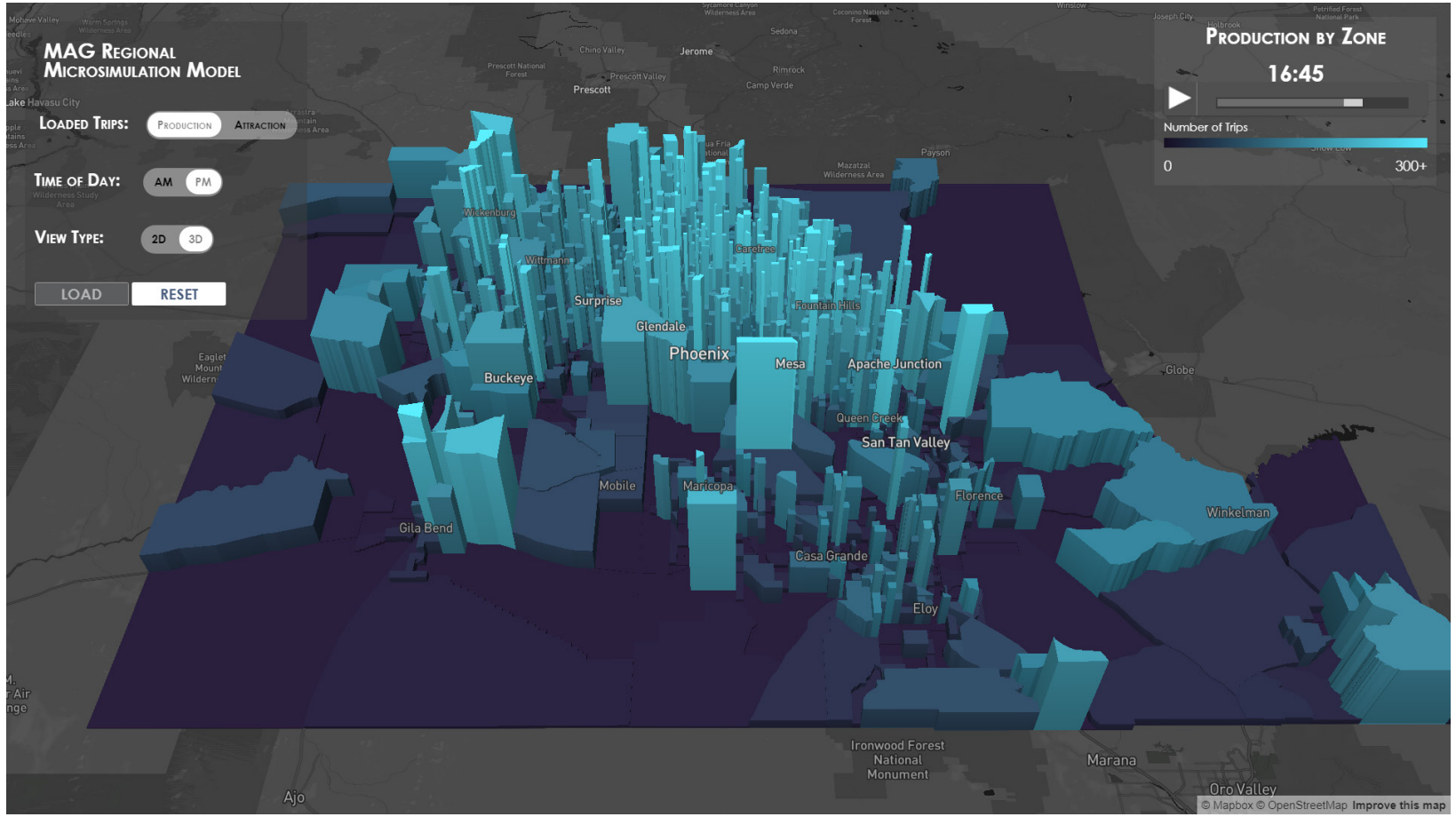
Time-Dependent Trip Tables: 2D View

AM Attraction by Zone



Time-Dependent Trip Tables: 3D View

PM Production by Zone



Concluding Remarks

- Greatly reduces time required to fulfill requests for microsimulations
- Data repository and data integration tool
- Applications on the regional scale

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