Development of a Truck Model for Memphis

presented to

Tennessee Model Users Group (TNMUG)

presented by

Cambridge Systematics, Inc.

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Outline

- Why Truck Models?
- Options for Memphis
- Development of External truck model
- Development of Internal truck model

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Why Truck Models?

- Trucks contribute to congestion
  - » 23 CFR 450 Congestion Management Process (c)(1)Methods to …identify and evaluate alternative strategies, …
- Requirement to study freight
  - » 23 CFR 450.306(a)(4) Increase accessibility and mobility of people and freight;
  - » 23 CFR 450.306 (a)(6) Enhance the integration and connectivity of the transportation system,…, for people and freight;

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Memphis Truck Model

- Freight is carried primarily by truck
  - » According to the FAF3:
    - 67% of the tons to/from/within TN Mem(phis) are by truck
    - 64% of the truck tons are IE/EI
- Trucks primarily travel to provide services
  - » From the FAF3 network in the TN Mem(phis) zone:
    - 609 center line highway miles
    - 35% of the DVMTT are by trucks that carry FAF freight
    - 65% of the truck DVMTT are by service (Non-FAF) trucks

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Memphis Truck Model

- **Estimation process**
  - » **Two models:**
    - **E-E/E-I/I-E (a.k.a. External) and**
    - **I-I (a.k.a. Internal).**
- **Estimation databases**
  - » **External - which is dominated by commodity truck flows, use a commodity flow database**
    - **i.e. TRANSEARCH**
  - » **Internal- which is dominated by service trucks, use a database that contains both freight and service trucks**
    - **i.e. ATRI GPS.**

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External Truck Model

- Develop Estimation Databases
- Develop Commodity Groups
- Develop Trip Generation Equations
- Develop Trip Distribution Equations

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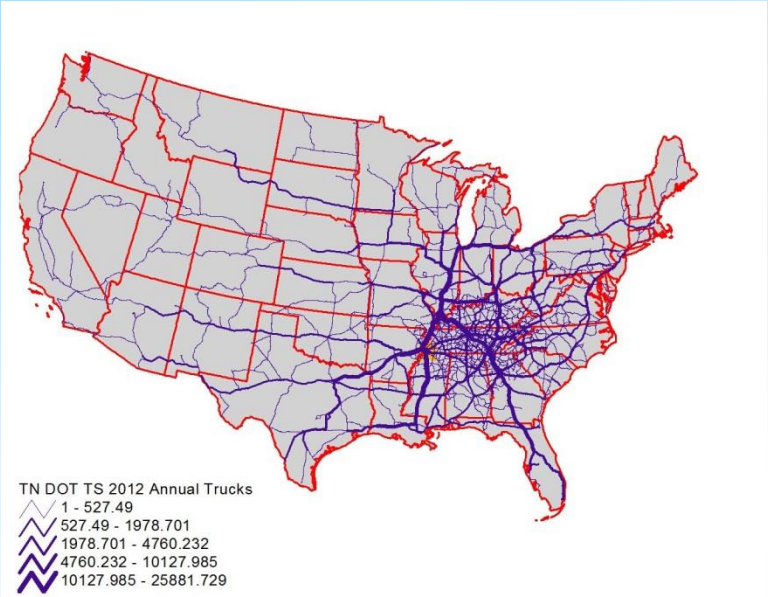
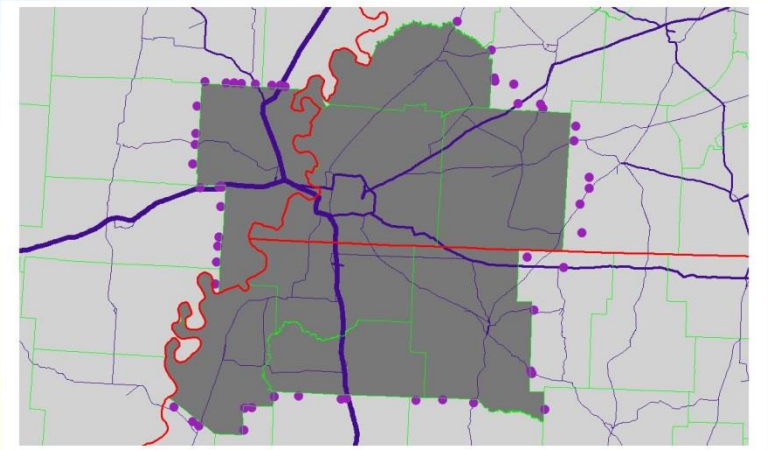
External Estimation Database

- Obtain and process TnDOT TRANSEARCH
- Window to Memphis MPO model boundary





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Commodity Groups

Commodity Group (CG) Name	CG #	SCTGs in CG	Daily Trucks Produced from I (of IE)		Daily Trucks Attracted to I (of EI)	
Farm Products	***1***	***SCTGs 01-05***	222	6%	***1,122***	***28%***
Food Products	2	SCTGs 06-09	262	7%	242	6%
Sand and Gravel	***3***	***SCTGs 11-15***	277	7%	***990***	***24%***
Gasoline & Fuel	4	SCTGs 16-19	277	7%	324	8%
Chemicals	5	SCTGs 20-23	167	4%	47	1%
Non-Durable Manufacture	6	SCTGs 24-30	91	2%	134	3%
Clay, Concrete, Glass	***7***	***SCTG 31***	***343***	***9%***	168	4%
Durable Manufacture	8	SCTGs 32-40	120	3%	141	3%
Waste	9	SCTG 41	232	6%	74	2%
Secondary and Mixed Freight	***10***	***SCTG 43 & SCTG 50***	***1,859***	***48%***	***827***	***20%***
Total			3,850	100%	4,068	100%

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External Model Trip Generation Equations

- Internal (TAZ) Truck Trips ends
  - » Develop NAICS3 employment by TAZ as explanatory variables.
  - » For each CG, for Internal Counties, identify best explanatory variable and rates for Production and Attraction equations
- External (Station) Truck Trip Ends
  - » Estimate from windowed TRANSEARCH
  - » FRATAR to observed truck counts

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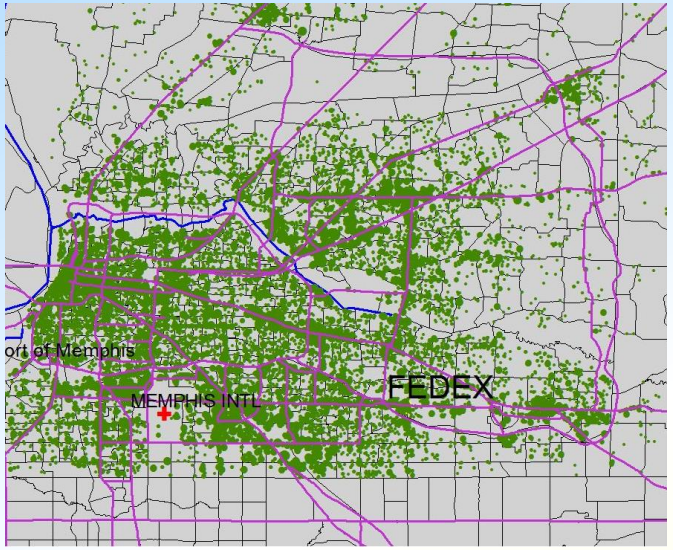
Develop NAIC3 Employment

- Obtain and process TNDOT Infogroup data
- Obtain and process Infogroup data for AR & MS Counties
- Result is NAICS3 employees per TAZ



Infogroup naics3 emp 3 tn counties.shp
- 1 - 4
- 4 - 9
- 10 - 19
- 20 - 49
- 50 - 99
- 100 - 249
- 250 - 499
- 500 - 999
- 1000 +

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I-E Truck Production Equations

Commodity Group		2012 Daily Trucks		Variable			R2
Code	Name	TRANSEARCH	Estimated	NAICS	Rate	t-Stat	
1	Farm	222	193	11	0.1931	6.192	0.846
2	Food	262	237	311	0.0497	15.146	0.970
3	Sand and Gravel	277	261	212 & 213	2.3728	4.847	0.770
4	Gasoline & Fuel	277	215	324	0.2481	9.507	0.928
5	Chemicals	167	179	325	0.0275	47.903	0.997
6	Non-Durable Manuf	91	68	31 & 32 NEC	0.0030	6.755	0.867
7	**Clay, Concrete, Glass**	**343**	**405**	**327**	**0.4167**	**8.943**	**0.920**
8	Durable Manuf	120	104	33	0.0037	19.360	0.982
9	Waste	232	242	Total	0.0004	54.296	0.998
10	**Secondary and Mixed Freight**	**1,859**	**1,899**	**42**	**0.0576**	**102.775**	**0.999**

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I-E Truck Production Equations adjusted

Commodity Group		2012 Daily Trucks		Variable			R2
Code	Name	TRANSEARCH	Estimated	NAICS	Rate	t-Stat	
1	Farm	222	193	11	0.1931	6.192	0.846
2	Food	262	237	311	0.0497	15.146	0.970
3	Sand and Gravel	277	261	212 & 213	2.3728	4.847	0.770
4	Gasoline & Fuel	277	215	324	0.2481	9.507	0.928
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8	Durable Manuf	120	104	33	0.0037	19.360	0.982
9	Waste	232	242	Total	0.0004	54.296	0.998
10	**Secondary and Mixed Freight**	**1,859**	**1,544**	**42**	**0.0173***	**NA**	**0.998**

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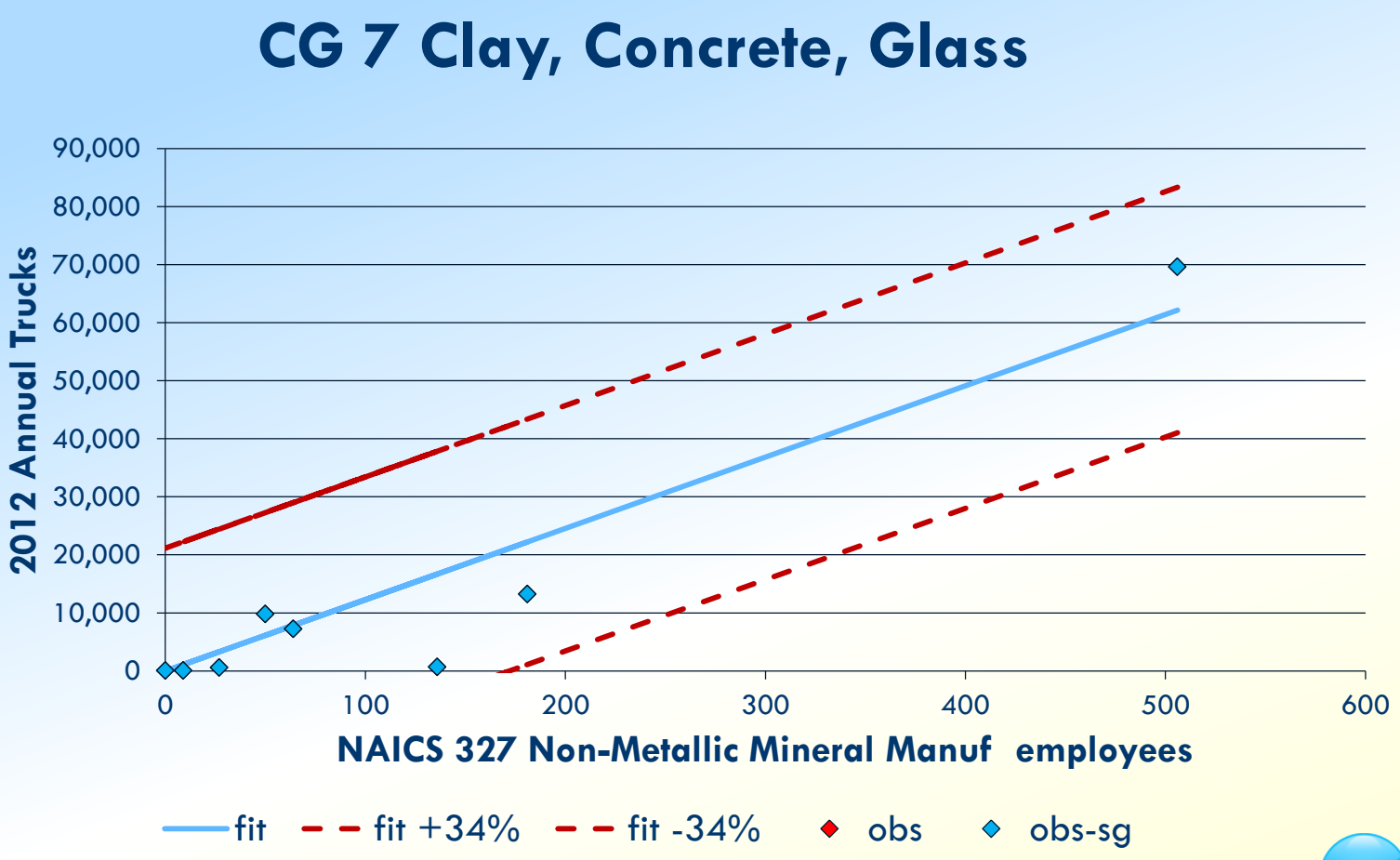
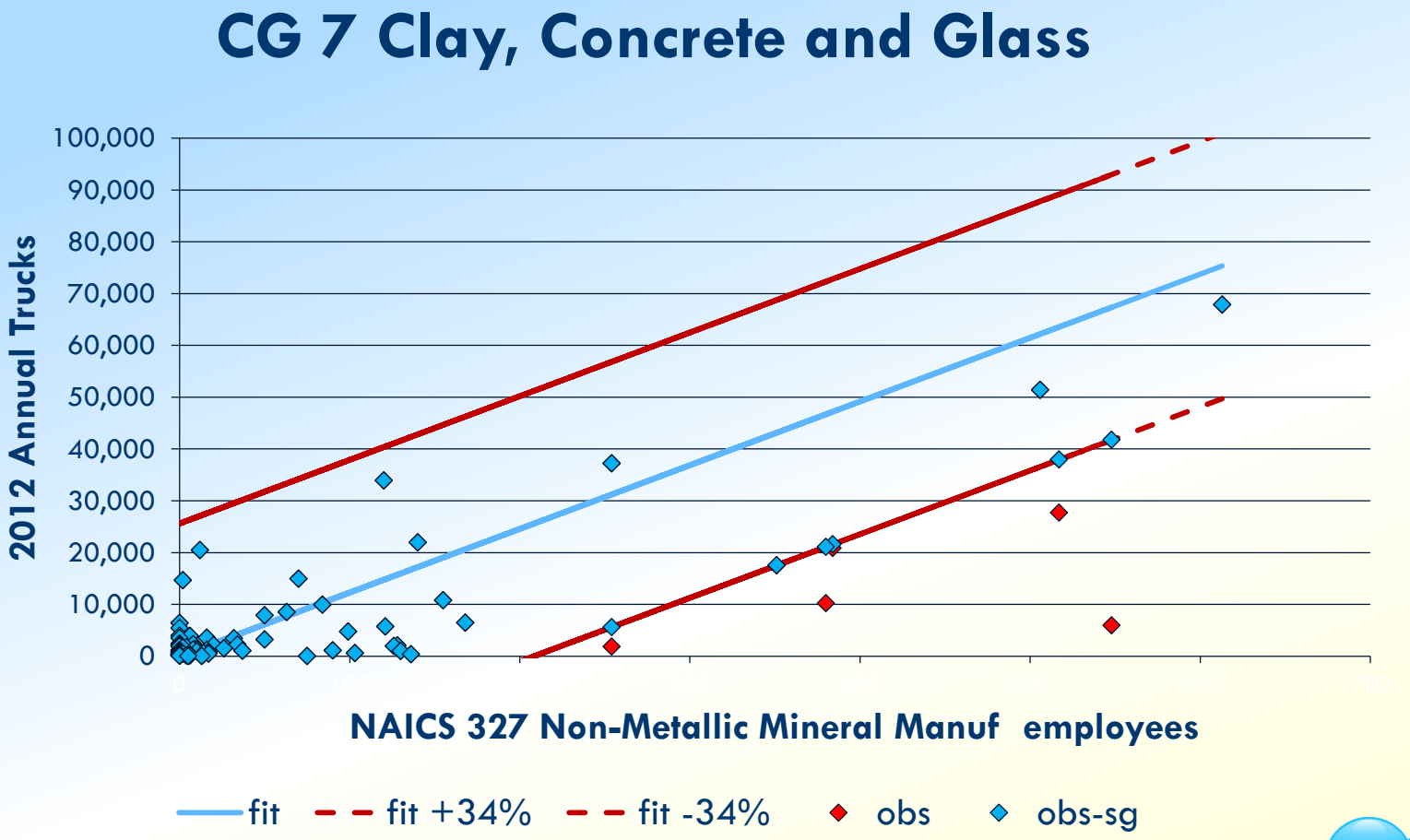
* Plus 978 trucks/day at special generators in Shelby Cnty

I-E TAZ Productions
(Memphis MPO)



I-E TAZ Productions
(Tennessee)



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I-E TAZ Productions
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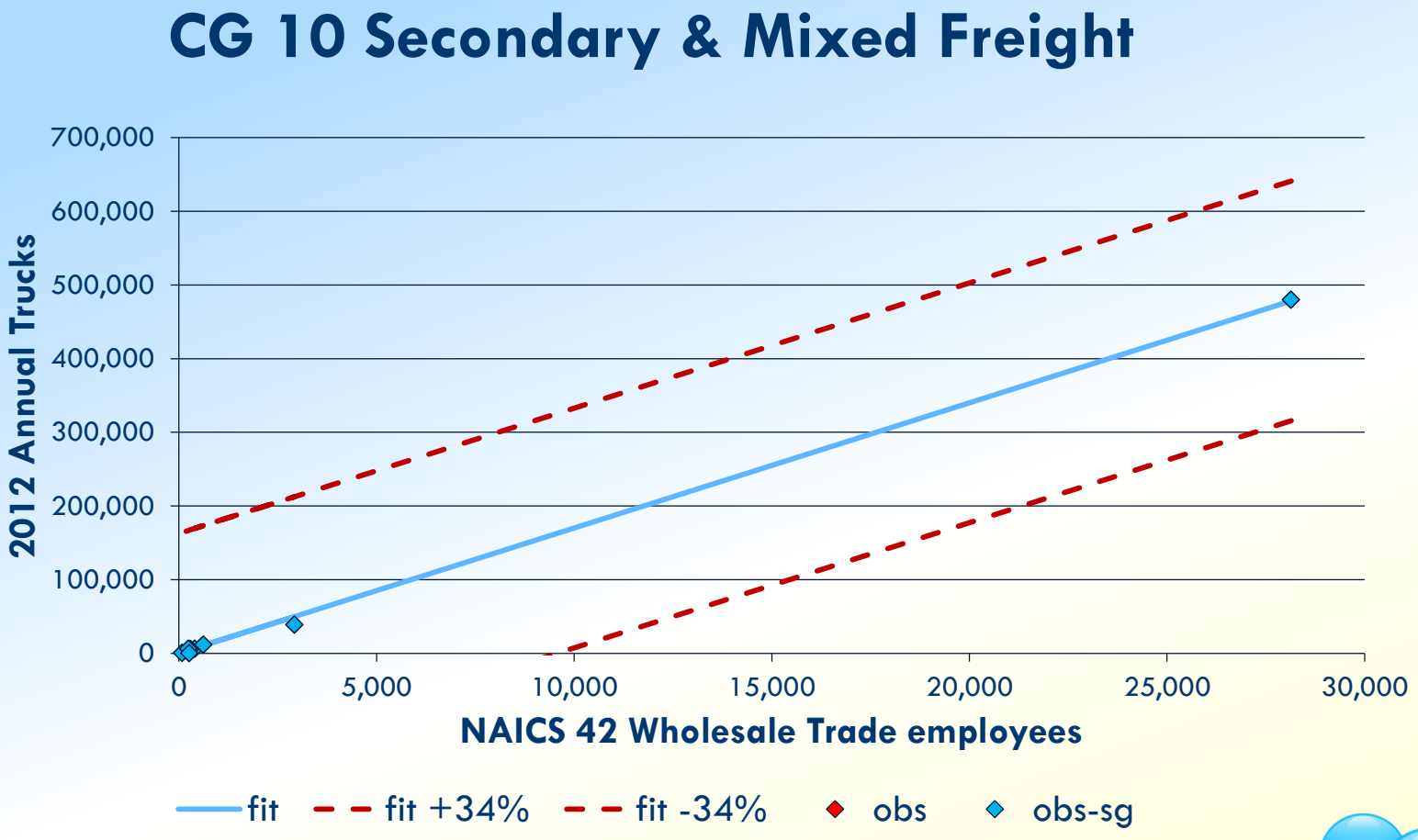
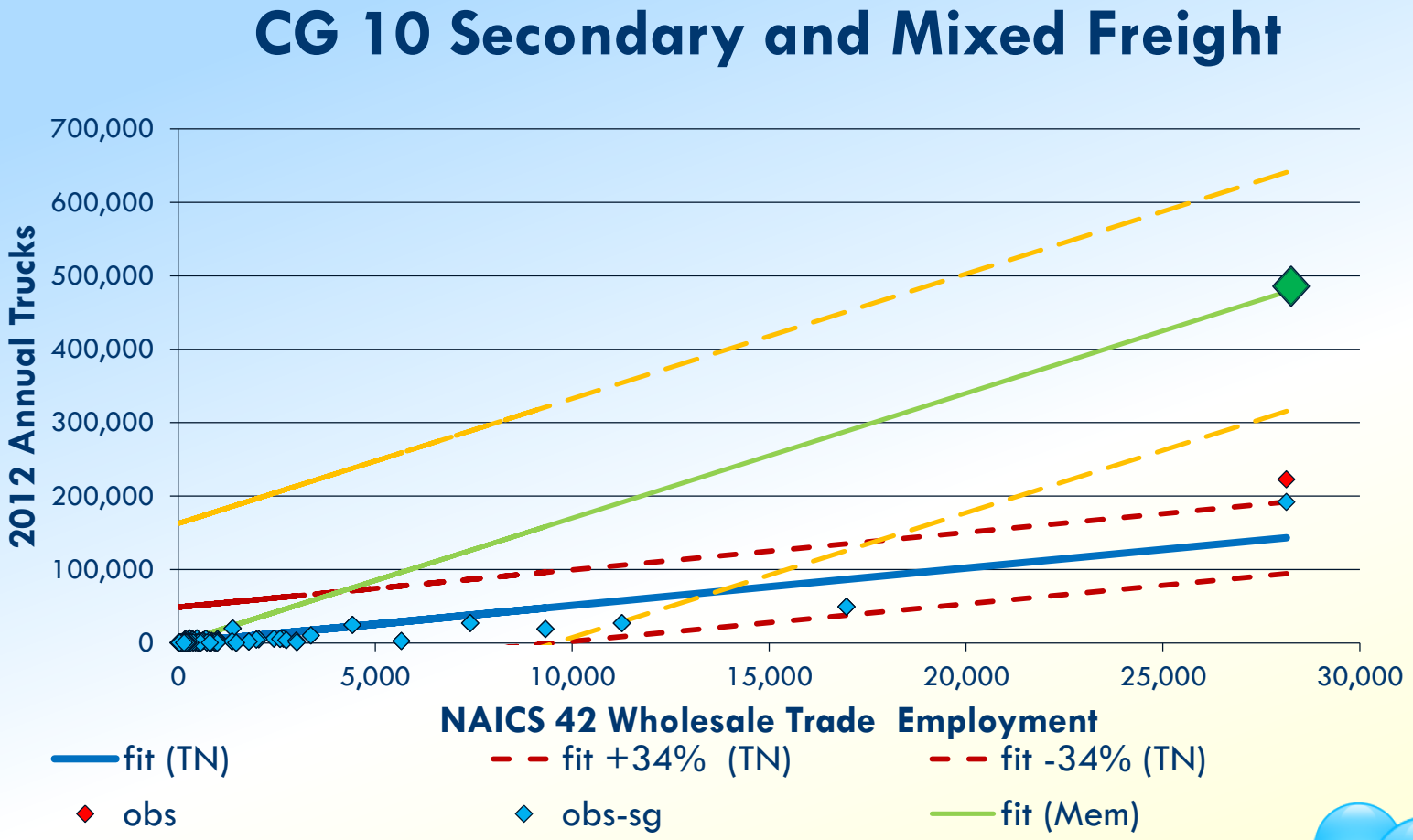


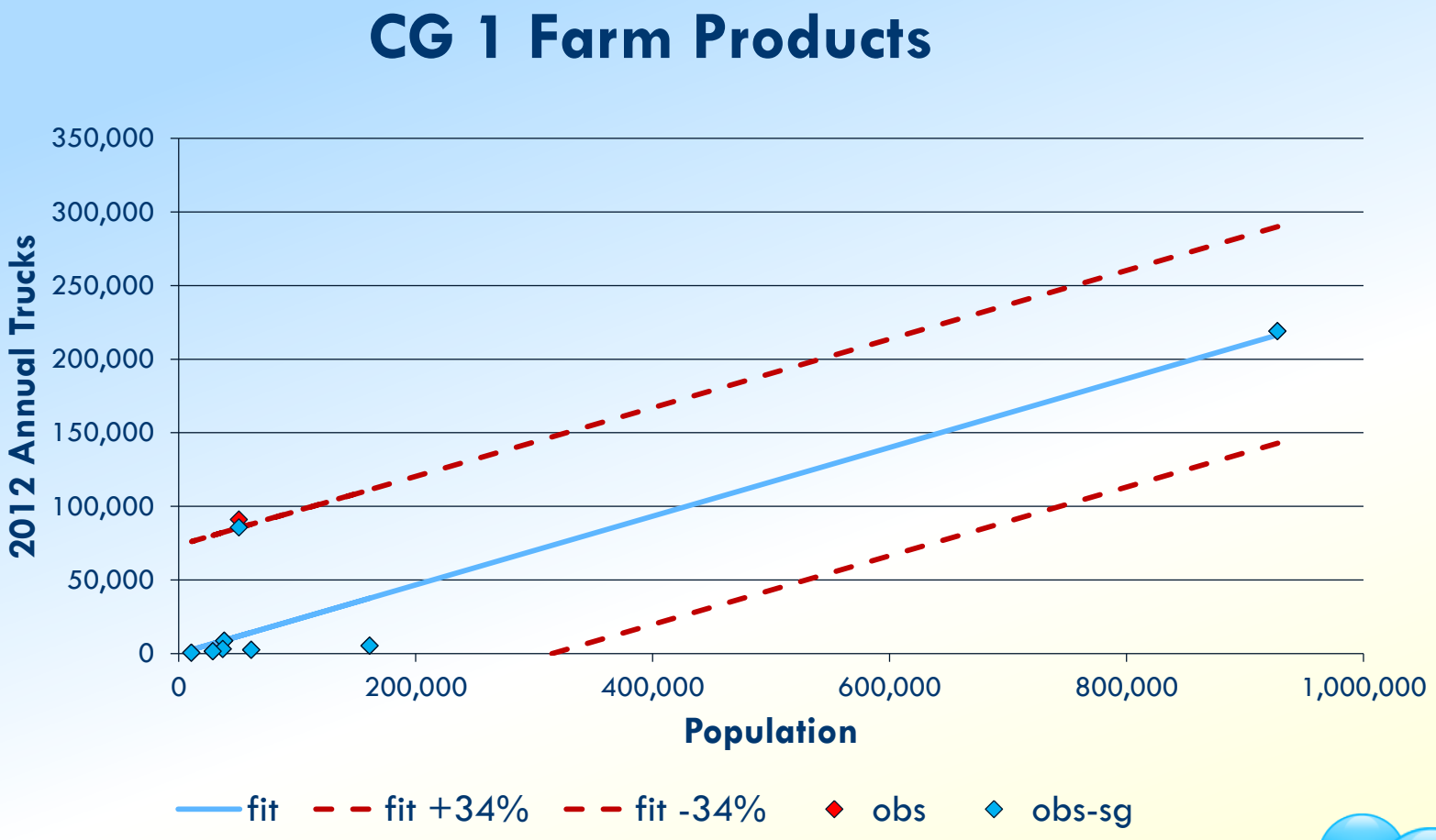
E-I TAZ Attractions
(Tennessee)



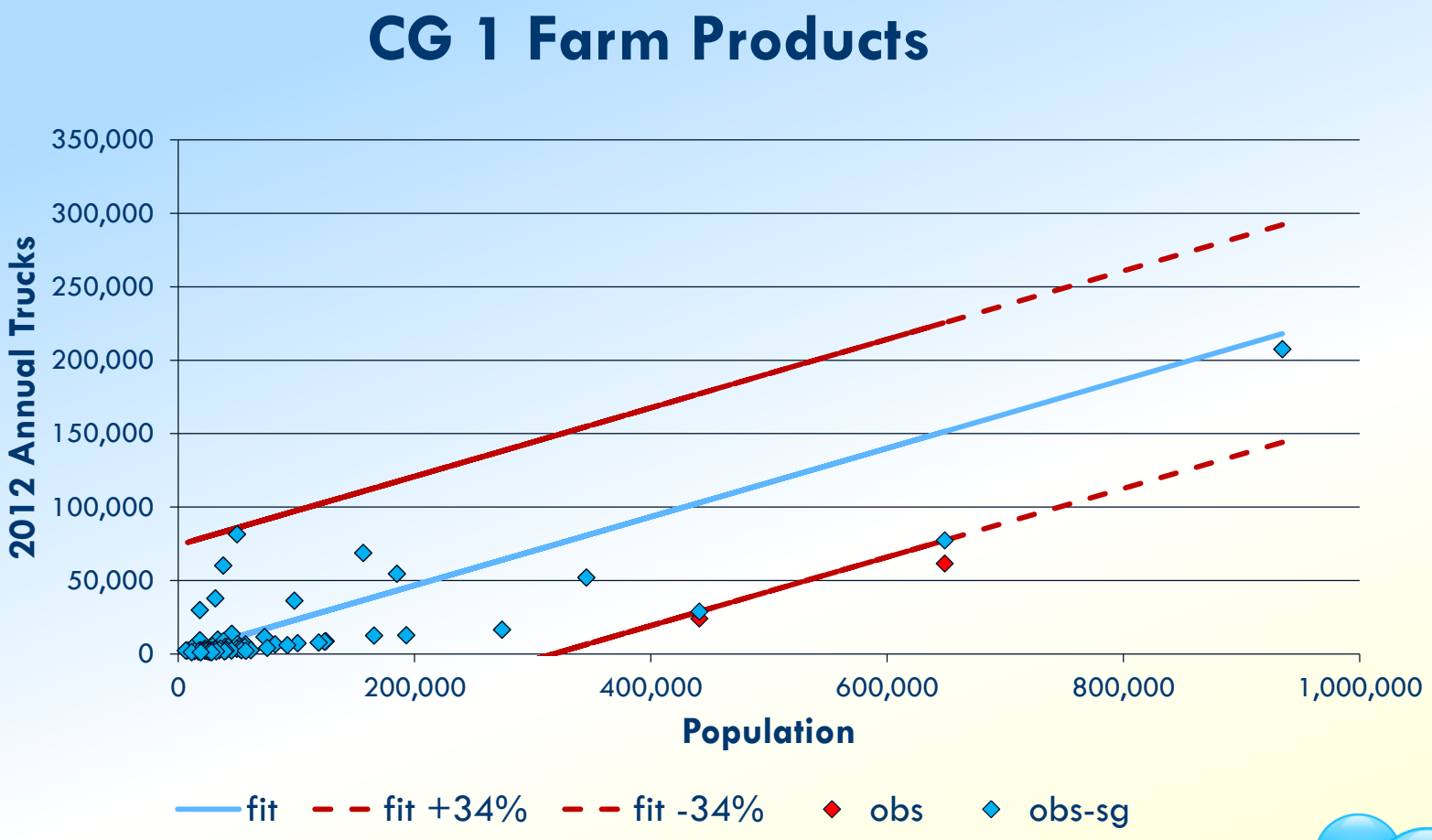
E-I Truck Attraction Equations

Commodity Group		2012 Trucks		Variable			R2
Code	Name	TRANSEARCH	Estimated	NAICS	Rate	t-Stat	
1	**Farm**	**331,024**	**312,577**	**POP**	**0.233**	**6.749**	**0.867**
2	Food	71,257	60,530	42	1.837	11.105	0.946
3	**Sand and Gravel**	**292,020**	**309,702**	**Pop**	**0.235**	**43.710**	**0.996**
4	Gasoline & Fuel	95,544	97,962	Pop	0.074	33.458	0.994
5	Chemicals	13,840	13,260	42	0.402	69.516	0.999
6	Non-Durable Manuf	39,500	39,252	42	1.191	82.240	0.999
7	Clay, Concrete, Glass	49,655	48,292	Pop	0.037	38.603	0.995
8	Durable Manuf	46,018	42,076	42	1.277	25.914	0.990
9	Waste	25,648	19,083	562	21.901	6.946	0.873
10	**Secondary and Mixed Freight**	**231,833**	**226,532**	**42**	**6.875**	**62.933**	**0.998**

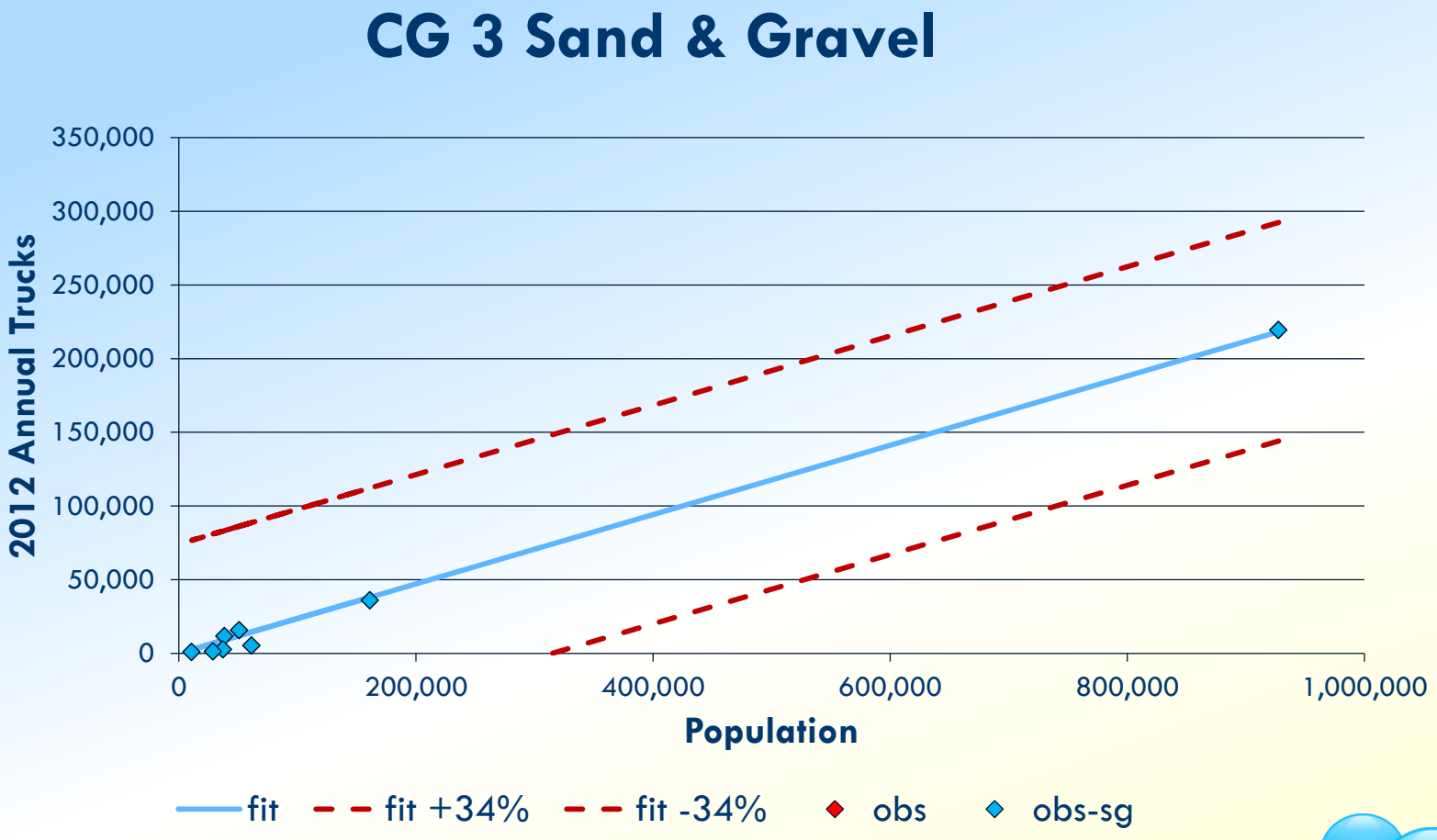
E-I TAZ Attractions
(Memphis MPO)



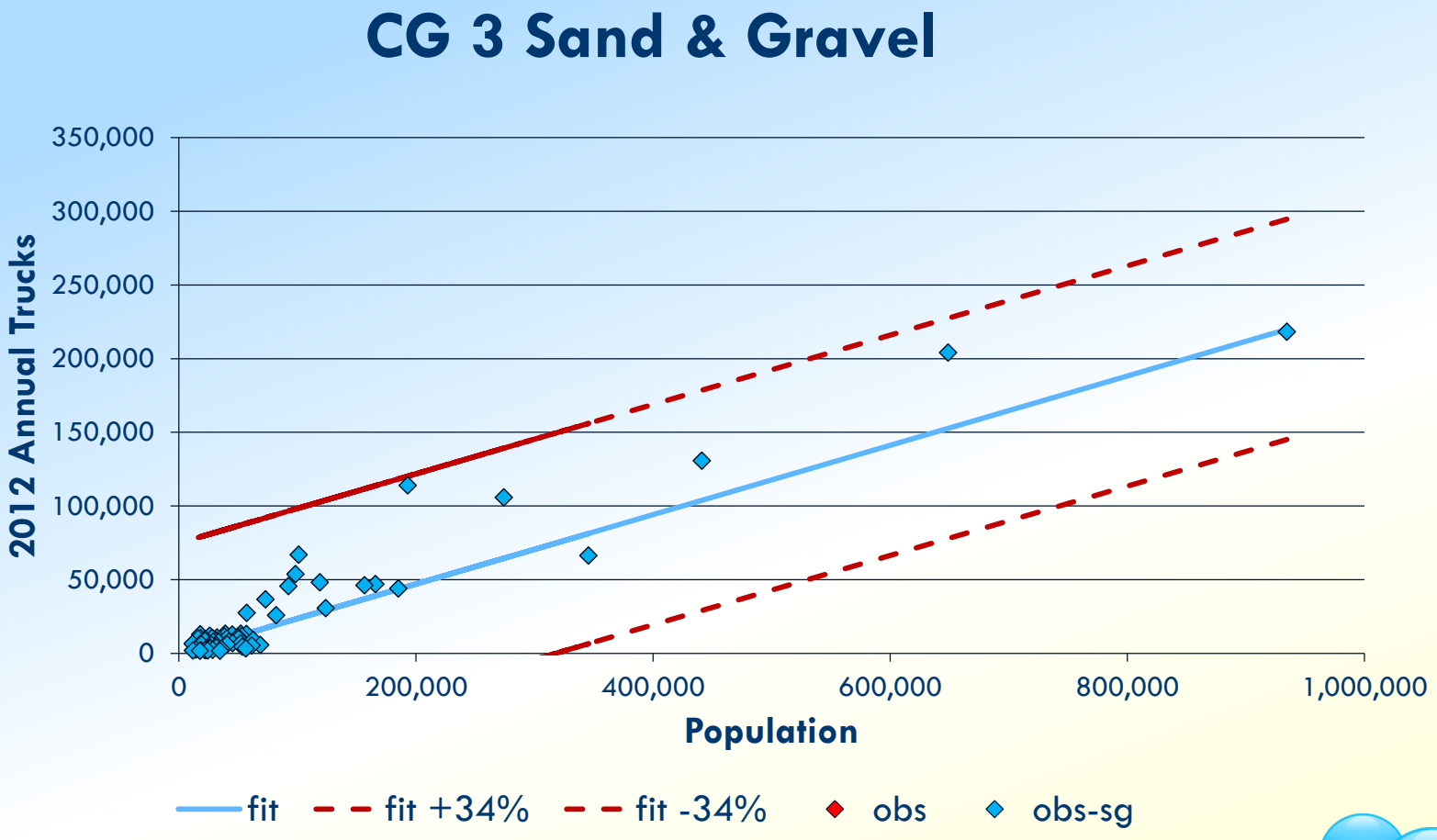
E-I TAZ Attractions
(Tennessee)



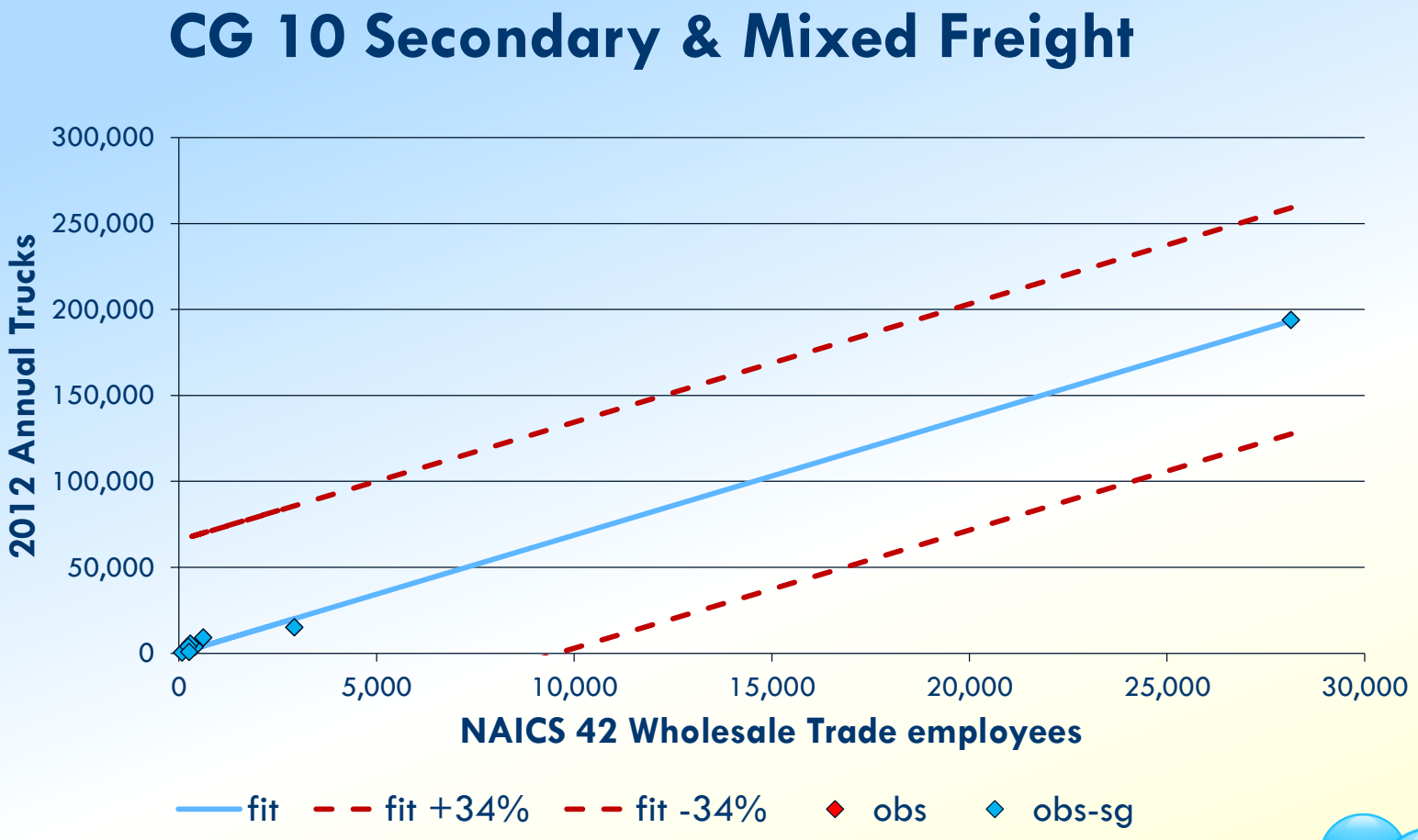
E-I TAZ Attractions
(Memphis MPO)



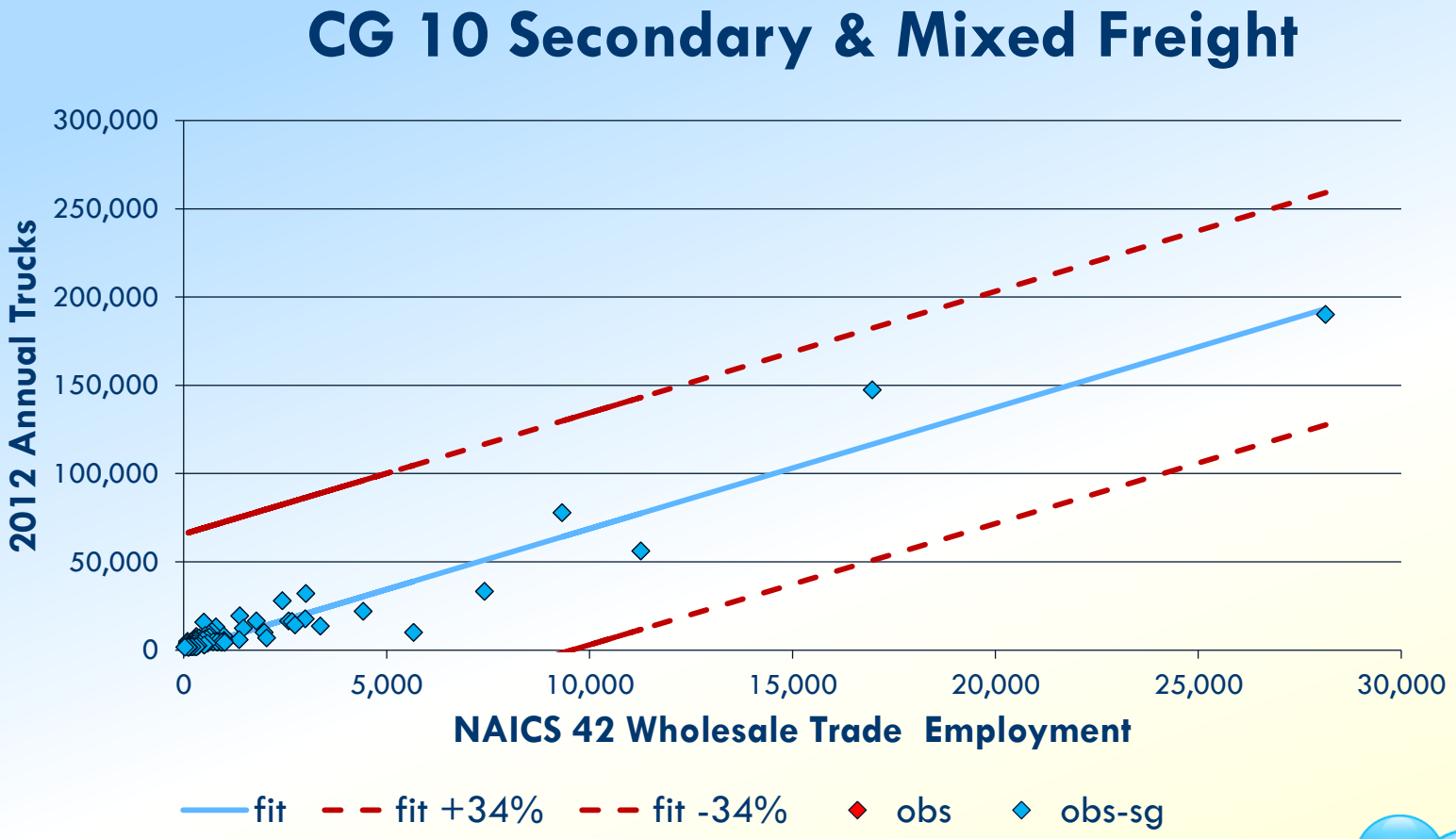
E-I TAZ Attractions
(Tennessee)



E-I TAZ Attractions
(Memphis MPO)



E-I TAZ Truck Attractions
(Tennessee)



External Ps and As

- Seed table is Windowed TRANSEARCH
- Row and column constraints are truck counts at External Stations
  - » No constraints for Internal counties
- FRATAR seed to counts
  - » O External Station summed over all Internal D TAZs = E-I P
  - » D External Station summed over all internal O TAZs = I-E A
  - » O External Station to D External Station is E-E

External Truck Model
Trip Distribution Equations

- **Use a Gravity Model**
  - » **Productions and Attractions from preceding**
  - » **"k-factor" set to zero for all I-I and E-E interchanges**
  - » **"Friction Factor " is a negative exponential function of distance**
    - **Coefficient is inverse of Average Trip Length (ATL)**
      - ♦ ATL varies by CG
      - ♦ Develop from Windowed TRANSEARCH
    - **Distance within region from network skim**
    - **Distance outside of region as reported in windowed TRANSEARCH**
      - ♦ Varies by CG and External Station

$$T_{ij} = \frac{k_{ij} P_i A_j F_{ij}}{\sum_{j=1}^{n} k_{ij} A_j F_{ij}}$$

$$F_{ij} = e^{-c * d_{ij}}$$

$$d_{ij} = di_{ij} + do_{ij}$$

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External Truck Model
Trip Distribution Factors

Commodity Group		Average Trip Length (miles)	Weighted Distance (mi) TS External Zones to Memphis External Stations	
Code	Name		I-40,TN	I-55, MS
1	Farm products	318	236	271
2	Food products	560	292	477
3	Sand and Gravel	307	229	309
4	Gasoline & Fuel	255	173	293
5	Chemicals	571	408	447
6	Non-Durable Manuf	517	335	430
7	Clay, Concrete, Glass	235	112	270
8	Durable Manuf	589	310	456
9	Waste	319	233	336
10	Secondary and Mixed Freight	406	284	505

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Internal Truck Model

- Pivot from QRFM equations
  - Light, Medium and Heavy trucks in QRFM
  - Heavy Trucks in ATRI
- Develop Trip Generation Equations
- Develop Trip Distribution Equations

Internal Truck Model
Trip Generation Equations

- All (TAZ) Truck Trips ends
  - » Develop QRFM "employment"by TAZ as explanatory variables.
  - » Use ATRI truck table as "observed" variable
    - By TNDOT SWM TAZs
  - » For heavy trucks, develop rates for TG equations
    - For TN DOT SWM TAZ in Tennessee
      - ♦ Sum QRFM variables from Memphis TAZs to SWM TAZs

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Internal Model Trip Generation Rates

QRFM Trucks				ATRI trucks
Variable	Light	Medium	Heavy	TN SWM TAZs
				R^2=0.652
Agriculture, Mining and Construction	1.110	0.289	**0.174**	**0.504**
Manufacturing, TCU and Wholesale Trade	0.938	0.242	**0.104**	**0.942**
Retail Trade	0.888	0.253	**0.065**	**0.784**
Office and Services	0.437	0.068	**0.009**	**0.0001**
Households	0.251	0.099	**0.038**	**0.0001**

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QAQC of ATRI Table on Memphis Network

- ODME
  - » ATRI table (I-I within Memphis as seed)
  - » Memphis MPO highway network
  - » Crosswalk between TN SWM TAZs and Memphis MPO TAZs
  - » Combination Unit truck counts as constraint
- Factored seed table by average of 1.72
- Consistent with I-I trips as 58% of all CU truck trips

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Internal Model Trip Generation Rates

Adjusted Rates trucks/day per employee (household)			
Variable	Light	Medium	Heavy
Agriculture, Mining and Construction	3.2152	0.8371	0.504
Manufacturing, TCU and Wholesale Trade	8.4961	2.1920	0.942
Retail Trade	10.7106	3.0516	0.784
Office and Services	0.0049	0.0008	0.0001
Households	0.0007	0.0003	0.0001

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Outliers from regression

- **Outliers defined as those whose observed trips are more than +/- 34% (½ SD) from estimated trips.**

- **Difference between observed trips and band of 1/2 SD is assumed as special generator value.**

SWM TAZ	ATRI	From rates	Special Generator	Estimated	Facility
2456	15,905	5,751	11,939	17,690	BNSF Memphis IM Yard
2457	13,355	6,662	8,801	15,463	BNSF Memphis IM Yard
2484	7,119	3,518	4,720	8,238	BNSF Memphis IM Yard
2518	9,997	1,682	8,839	10,522	Port of Memphis

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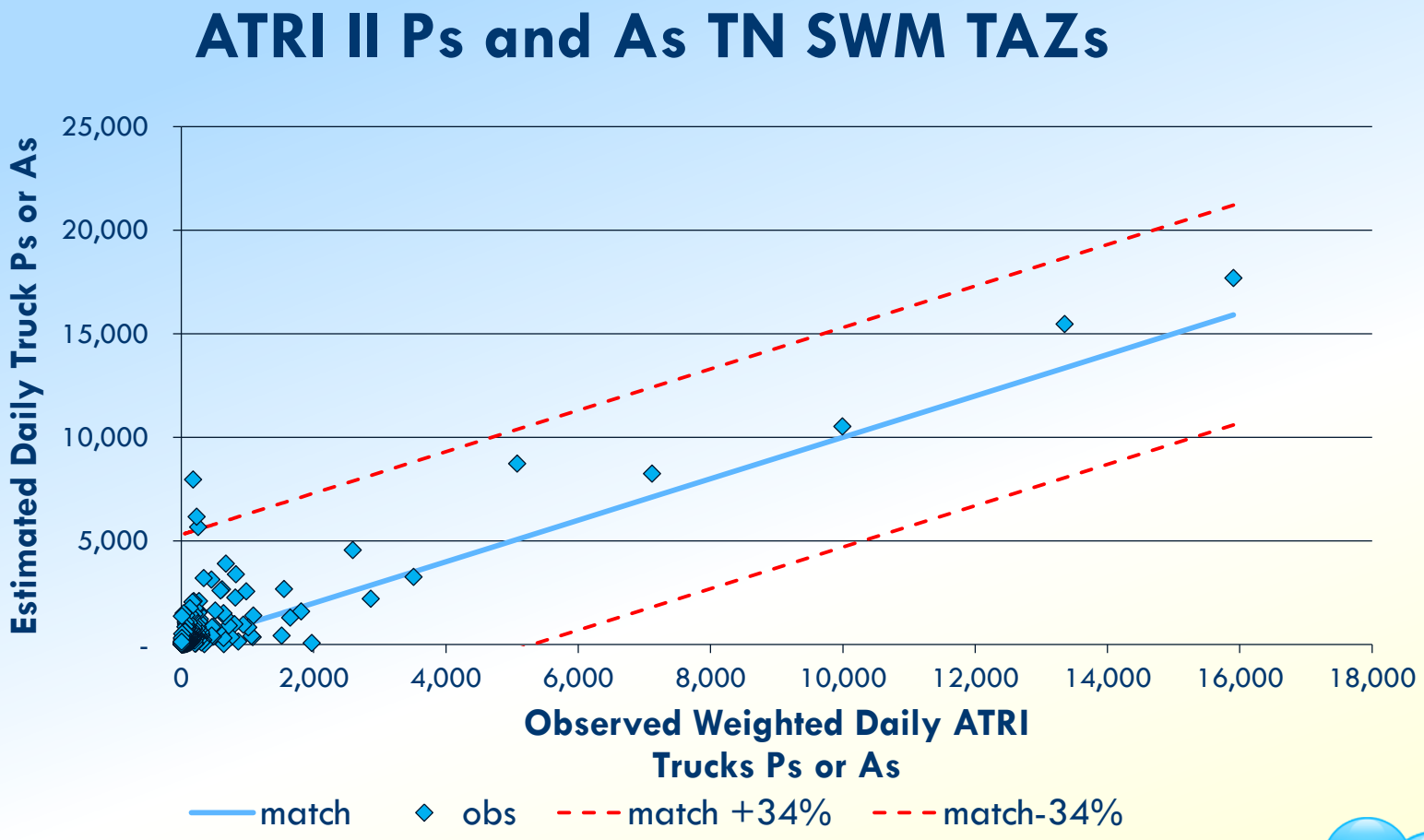
Internal Truck Model Trip Generation



Internal Truck Model
Trip Distribution Equations

- **Use a Gravity Model**
  - » **Productions/Attractions from preceding**
  - » **"k-factor" set to zero for all but I-I interchanges**
  - » **"Friction Factor " is a negative exponential function of time**
    - **Coefficient is computed by TransCAD "Calibrate Gravity Model"**
      - ♦ AM skim times from Memphis MPO model
      - ♦ "Observed" ATRI truck table

$$T_{ij} = \frac{k_{ij} P_i A_j F_{ij}}{\sum_{j=1}^{n} k_{ij} A_j F_{ij}}$$

$$F_{ij} = e^{-c * t_{ij}}$$

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Internal Truck Model
Friction Factor Coefficients

QRFM Trucks			ATRI trucks	
Category	Coeff	1/ Coeff	Coeff	1/ Coeff
Light	-0.08	12.5 min	*-0.249*	*4.02 min*
Medium	-0.10	10.0 min	*-0.310*	*3.22 min*
Heavy	**-0.03**	**33.3 min**	**-0.093**	**10.7 min**

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Combined Truck Model

- Tables from Internal and External Truck Models are combined prior to assignment.
- Internal Truck Trip ends are function of SED in each TAZ
- Distribution of trips within Memphis model is based on network skims.

Questions?

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