Development of MAG's Truck Travel Model from Truck Travel Surveys and Commodity Flow Data

presented to

Maricopa Association of Governments

presented by

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Maricopa Association of Governments

Importance of Truck Model

- Goods movement forecasting and predicting future truck volumes a prerequisite for development of regional transportation plans

- Truck movements are major consideration for economic vitality, congestion and travel demand management, air quality conformity analysis, road infrastructure improvements

- Truck VMT is approximately 33 percent of overall VMT (MAG Model)

- Truck contribution to PM-10 and NOx-disproportionately high (among vehicular emissions)

2008 PM-10 and NOx Emissions by Vehicle Type

Vehicle Type	PM-10 Emissions	Percent	NOx Emissions	Percent
Light Duty Vehicles	1,286	35%	36,875	47%
Medium Duty Trucks	667	18%	11,742	15%
Heavy Duty Trucks	1,728	47%	29,649	38%

Source: Maricopa Association of Governments, EPA MOVES2010a Model
Units: Annual Tons

Outline

- Background and Unique Features

- Data Collection and Processing

- Internal Truck Model Development

- External Truck Model Development

- Truck Model Validation and Integration

- Forecast Year Model and Results

- Future Truck Model Improvements

Background/Objectives

- First Urban Truck Model in USA
  - » Developed by CS in 1992 for MAG
  - » Key reference and case study in 1996 FHWA Quick Response Freight Manual

- Resources available
  - » 2007 MAG Internal Truck Travel Survey
  - » 2007 TRANSEARCH Database

- Objectives: To update Internal and External Truck Travel Model

Unique and Innovative Features

- Collected O-D travel information from trucks that travel within the MAG region using different surveying techniques for different sectors

- Instead of using a single gravity model by truck size distributed trucks by purpose in a series of gravity models using land use-to-land use interchanges

- Developed equations to forecast external freight flows based socio-economic activity at the zonal level

- Integrated land use-based internal truck model and commodity flow-based external truck model into a "hybrid" truck model

Data Collection

Survey Process

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                    Truck Surveys
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Establishment Surveys →
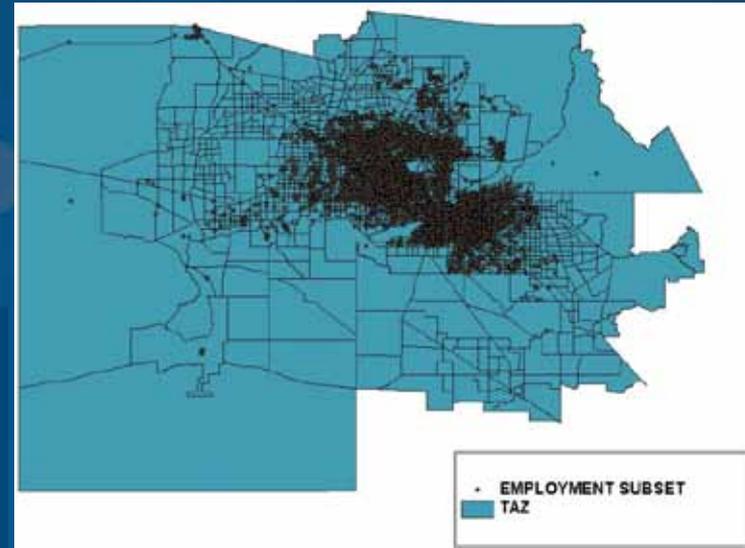- Warehouse/ Distribution Centers/ Terminals
- Manufacturing

Truck Trip Diaries →
- Local, Pickup, and Delivery
- Construction
- Mail/Parcel
- For-hire
- Retail

Research/ National Databases →
Service Industry
- Safety
- Utility
- Public Service
- Personal Business

Geographic Distribution of MAG Employment Database Sampling Frame

EMPLOYMENT SUBSET
TAZ

Sources of Sample

- MAG Employment Database
- Fleet Seek
- ATA Fleet Directory
- U.S. Data Corporation

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Survey Results (establishment surveys)

▊ Phone surveys using CATI System

▊ Pre-Tests – 10 surveys

▊ Full Survey – 552 completes

Sampling Framework
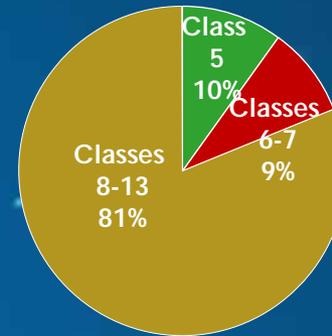
Sector	Frequency	Percent
Manufacturing	3,030	49%
Wholesale Trade	2,730	44%
Warehousing / Transportation	383	6%
Total	6,143	100%

Number of Surveys

Sector	Number of Surveys
Manufacturing	275
Wholesale Trade	198
Warehousing / Transportation	89

Warehousing/ Transportation

Class 5 10%
Classes 6-7 9%
Classes 8-13 81%

Manufacturing

Class 5 11%
Classes 6-7 20%
Classes 8-13 69%

Wholesale Trade

Class 5 10%
Classes 6-7 22%
Classes 8-13 68%
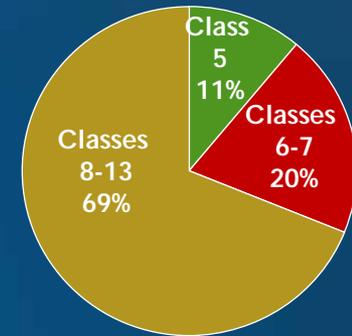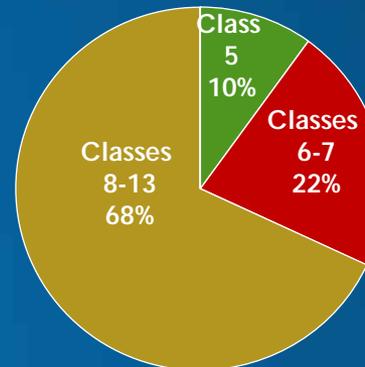
FHWA Truck Class	Description
Class 5 Trucks	2 axle 6 Tire Single Unit
Class 6-7 Trucks	3+ axle Single Units
Class 8-13	Combination Trucks

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Survey Results (trip diary surveys)

Number of Surveys

Survey Question	Survey Response	Frequency
Truck Size	33,001 lbs and above	134
	14,001 – 33,00 lbs	60
Number of Axles	Combo Unit, 4+ axle (8-13)	91
	Single Unit, 2-4 axle (5-7)	84
Fuel Type	Diesel	223

- Mail-in/Mail-back surveys
- Pre-Tests – 24 diaries, 132 stops
- Full Survey – 236 Diaries, 1304 stops

Sampling Framework

Aggregate Business Sector	NAICS Codes in Sector	Number of Firms	Percent of Firms
Construction / Agriculture / Mining	11, 21, 23	3,860	33%
Retail Trade	44, 45	2,791	24%
Accommodation & Food Services	72	2,754	23%
Delivery / Publishing	48	689	6%
Equipment / Rental / Leasing	49, 51, 53		
Other Services with Product Delivery	32, 54, 56, 81	1,603	14%
Total		11,697	100%

Percentage of Stops

Location	Percentage
All other location	10%
Industrial	7%
Retail store/restaurant/mall	8%
House/other residential	11%
Warehouse/wholesale store	17%
Construction site	24%
My company employer	23%
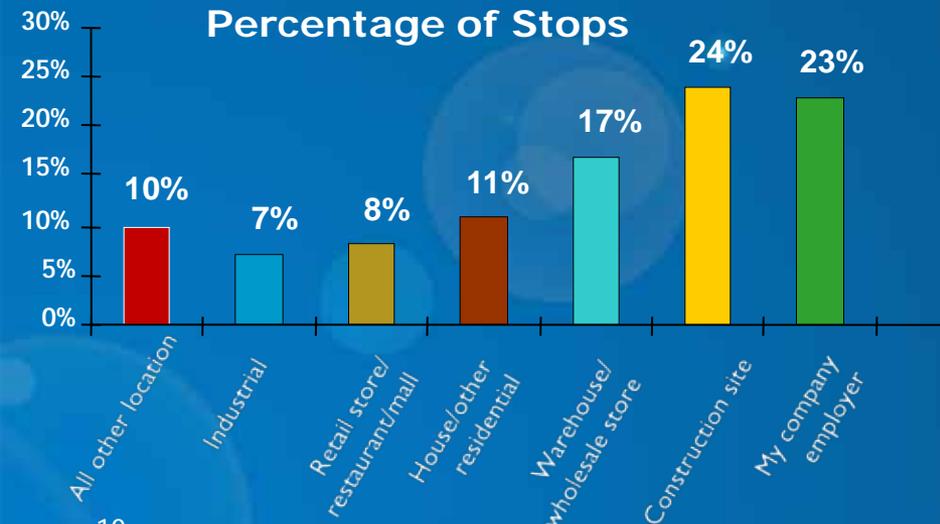
Internal Truck Model

Internal Truck Trip Generation

- 2-digit NAICS employment data (13 categories)

- Land-use based trip rates (P & A) from expanded surveys

- Internal truck trip ends by land use and truck type

•My Employer
•Retail
•Construction
•Farming
•Mining
•Household
•Warehousing
•Transportation
•Industrial
•Service (Office, Government, Other)

Internal Truck Trip Distribution

- Gravity models based on friction factors by truck type
- LU-to-LU trip exchange proportions
  - » Production percents shown sum across to 100%
  - » Attraction percents, not shown, restated to sum down to 100%

	1 MY EPLOYER	2 HOUSE HOLD	3 OFFICE	4 GOVT	5 RETAIL	6 CONST.	7 WARE HOUSE	8 INDUST.	9 TRANSP.	10 FARM	11 MINE	12 OTHER
1 MY COMPANY/EMPLOYER LOCATION	10%	6%	0%	1%	2%	33%	36%	5%	2%	1%	3%	2%
2 HOUSE/OTHER RESIDENTIAL	18%	42%	14%	0%	2%	13%	10%	0%	0%	0%	0%	0%
3 OFFICE/BANK/MEDICAL/REPAIR	12%	0%	12%	63%	0%	12%	0%	0%	0%	0%	0%	0%
4 GOVERNMENT*	30%	0%	0%	0%	70%	0%	0%	0%	0%	0%	0%	0%
5 RETAIL/STORE/RESTAURANT/MAIL	13%	4%	0%	4%	40%	16%	9%	0%	13%	0%	0%	0%
6 CONSTRUCTION SITE	35%	2%	1%	0%	1%	44%	4%	3%	2%	0%	6%	3%
7 WAREHOUSE/WHOLESALE STORE	45%	6%	0%	0%	4%	5%	35%	2%	2%	0%	0%	2%
8 INDUSTRIAL	29%	0%	0%	0%	0%	20%	4%	31%	16%	0%	0%	0%
9 TRANSPORTATION HUB	7%	0%	0%	0%	14%	24%	14%	14%	14%	0%	0%	14%
10 FARM	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
11 MINE	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%
12 OTHER	7%	5%	0%	0%	0%	14%	9%	9%	5%	0%	0%	51%

* Including GOVERNMENTBUILDING/SCHOOL/MILITARY BASE/HOSPITAL

Internal Truck Trip Distribution (contd)

- Conventional gravity model calculates all truck trips between zones "i" and "j"

  » Based on Productions in "i", Attractions in "j" and Friction Factor (FF) between zones "i" and "j"

- Interchange gravity model calculates truck trips from the land use in "i" to the land use in "j"

  » Based on Productions in "i", Attractions in "j" and Friction Factor (FF) between zones "i" and "j";   and

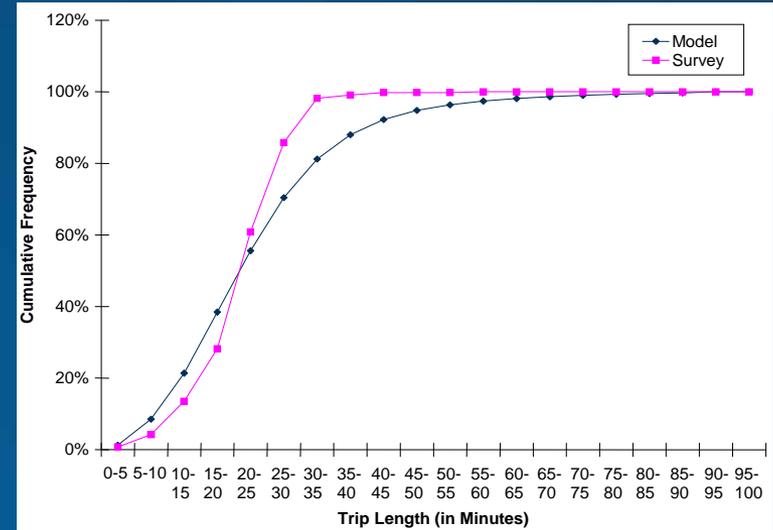 » Based on the percentage those land uses have of total productions or attractions for that exchange

$$T_{ilu_m lu_n} = PctP_{lu_m lu_n} * P_{ilu_n} * \frac{PctA_{lu_n lu_m} * A_{jlu_n} * FF_{ij}}{\sum_j PctA_{lu_n lu_m} * A_{jlu_n} * FF_{ij}}$$

Trip Distribution Results

Medium-Truck Trip Length Frequency Distribution
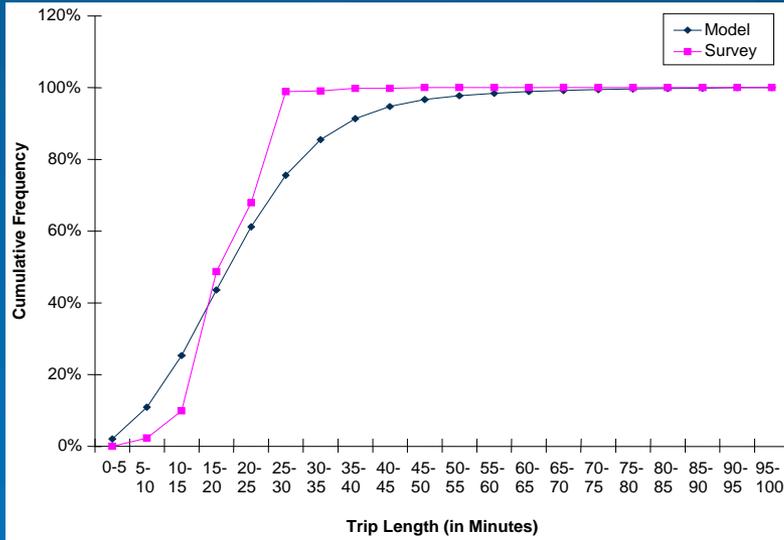
Heavy-Truck Trip Length Frequency Distribution

Average Trip Length by Truck Type

Truck Type	Survey (In Minutes)	Model (In Minutes)	Difference (In Minutes)	Trips
Light	N/A	15.89	N/A	1,732,178
Medium	20.13	23.52	3.39	646,311
Heavy	23.11	25.53	2.42	145,855

External Truck Model

External Truck Model

- External model based on TRANSEARCH commodity flows

  » TRANSEARCH is annual commodity flow database developed by IHS Global Insight

  » Represents flows at Statewide, Countywide and Zip Code Tabulation Area (ZCTA) level

  » Includes Payload Factors for each commodity

  » TRANSEARCH has 32 commodities (STCC2) which were grouped into 10 major commodity groups

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External Trip Generation

CG Number	Commodity Group (CG) Name	STCC2 Names
1	Farm	Agriculture, Forest Products, Fish
2	Mining	Metallic Ores, Crude Petroleum, Nonmetallic Minerals, Ordnance
3	All Consumer Manufacturing	Food, Tobacco, Textiles, Apparel, Leather
4	Lumber	Lumber
5	(Non-Consumer) Nondurable Manufacturing	Paper, Chemicals, Petroleum, Rubber/Plastics
6	(Non-Consumer) Durable Manufacturing	Furniture, Metal, Metal Products, Machinery, Electrical Equipment, Transportation Equipment, Instruments, Misc Mfg Products
7	Printing	Printed Goods
8	Miscellaneous Freight	Waste, Misc Freight Shipments, Waste
9	Empty trucks	Shipping Containers
10	Warehousing	Secondary and Drayage

- **10** CGs serve as 10 trip purposes for external model

  » Commodity Flow = f (Employment)

  » STCC2 (TRANSEARCH) and SIC2 (employment) production relationships by same code

  » Using SIC2 and NAICS2 crosswalk, STCC2 = f (NAICS2)

  » STCC2 (TRANSEARCH) and SIC2 (employment) attraction relationships by regression

External Truck Production Model

| CG #	Name	Variable	Coefficient	t-stat	R^2
1	Farm	Natural Log of Agriculture	125.2	9.226	0.810
2	Mining	*	*	*	*
3	All Consumer Manufacturing	Consumer Manf	8.281	11.931	0.785
4&5	(Non-consumer) Nondurable Manufacturing Including Lumber	Non Durable Manf	12.989	10.356	0.691
6	(Non-consumer) Durable Manufacturing	Non Durable Manf	2.715	7.154	0.795
		Durable Manf	0.451	4.555	
7	Printing	Durable Manf	0.434	12.973	0.816
8	Miscellaneous Freight	Natural log of Warehousing	0.036	8.073	0.739
9	Empty trucks	Sum of total truck attraction	0.287	68.083	0.994
10	Warehousing	Wholesale Trade	0.532	8.719	0.613

- Mining identified as a special generator

- Combined CG 4&5 due to limitation in detail in NAICS2

- CG6 function of two employment variables

- Empty trucks produced as a function of attraction

External Truck Attraction Model

CG #	Name	Variable	coefficient	t-stat	R^2
1	Farm	Consumer Manf	0.266	1.616	0.783
		Wholesale	0.272	6.599	
2	Mining	Durable Manf	8.492	10.619	0.831
3	All Consumer Manufacturing	Consumer Manf	1.626	1.613	0.782
		Wholesale	1.659	6.591	
4&5	(Non-consumer) Nondurable Manufacturing incl. Lumber	Wholesale	3.662	8.461	0.757
6	(Non-consumer) Durable Manufacturing	Wholesale	3.059	8.448	0.756
7	Printing	Wholesale	0.13	8.441	0.756
8	Miscellaneous Freight	Non Durable Manf.	0.001	10.618	0.831
9	Empty trucks	Sum of total truck production	0.39	29.111	0.91
10	Warehousing	Wholesale	2.701	8.866	0.759

- Different variables than production for each CG attraction

- Combined CGs 4 & 5 due to limitation in detail in NAICS2

- CG1 and CG3 attractions driven by two employment variables

- Empty trucks attracted based on total production

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Special Generators
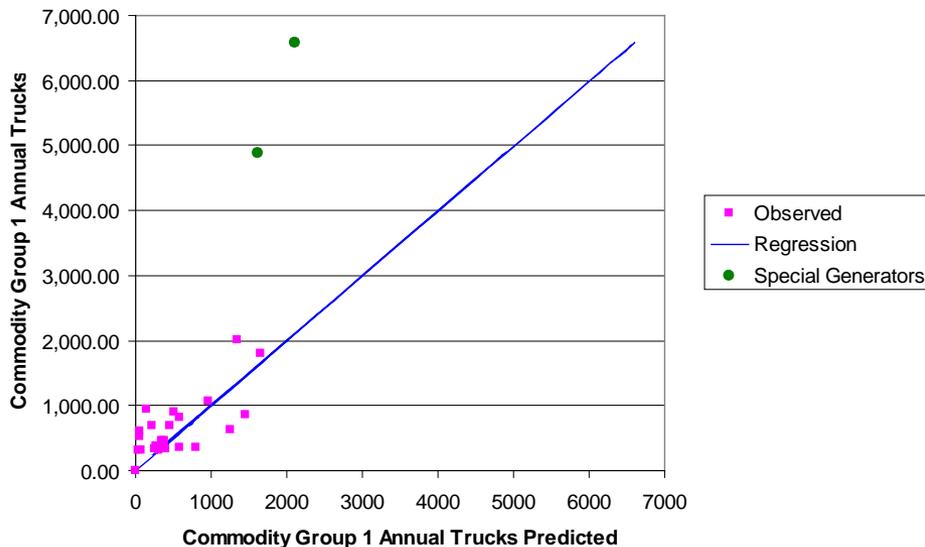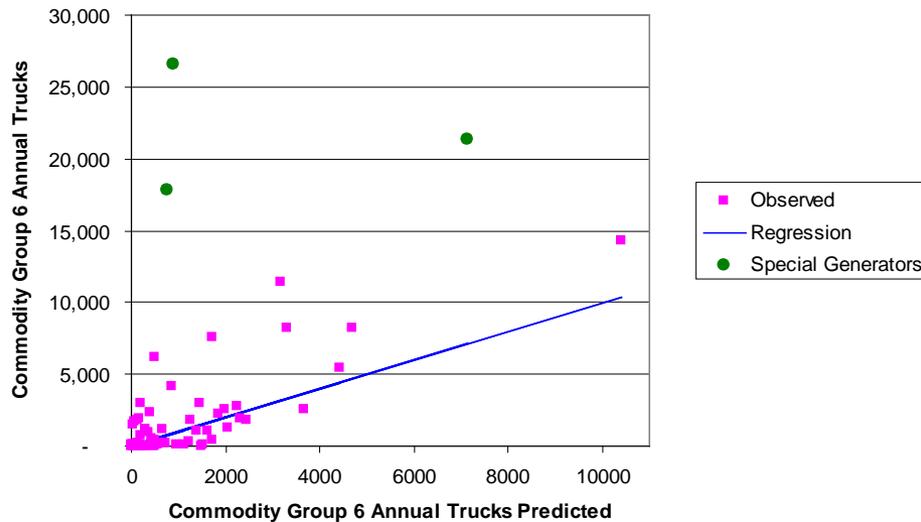
- Examples
  - » 'Durable manufacturing' production
    – observed vs. predicted
  - » 'Farm' attraction
    – observed vs. predicted

- Outliers identified as special generators

- GeoFreight database (BTS) used to locate TAZs of freight terminals for that special generator tonnage

External Trip Distribution

- Internal truck trip ends (for 'I' in IE & EI) from trip generation

- Need to identify External truck trip ends
  - » Total truck trip ends from MAG's external station truck counts
  - » TRANSEARCH annual flows, converted to daily truck trip table, used as initial "Seed Table"
  - » TransCAD's IPF used with "Seed Table" with counts as targets to find non internal truck trip table
    - Identify E trip ends of IE & EI flows for use in trip distribution
    - Retain E-E flows for later use
  - » Distribute EI and IE trips using gravity model

Integration & Validation

Integrate Internal & External Models

- Internal truck trips added to External truck trips to produce total truck trip tables by truck type

- Internal and External truck model scripts integrated with MAG's passenger travel model scripts

- Calibration and validation of truck model was done with 2008 base year travel model

Base Year Validation
Selected Jurisdictions

Jurisdictions	Counts*			Integrated Model			Integrated Model - Counts	
	Medium (Class 5-7)	Heavy (Class 8-13)	Medium & Heavy	Medium (Class 5-7)	Heavy (Class 8-13)	Medium & Heavy	Medium & Heavy	Medium & Heavy %
Avondale	2,579	1,817	4,396	1,823	1,948	3,771	-625	-14%
Chandler	5,710	6,283	11,993	5,099	5,653	10,752	-1,241	-10%
Gilbert	3,179	1,470	4,649	1,097	1,343	2,440	-2,209	-48%
Glendale	9,828	8,505	18,333	8,262	8,775	17,037	-1,296	-7%
Mesa	9,076	10,080	19,156	6,390	7,144	13,534	-5,622	-29%
Peoria	4,739	5,298	10,037	5,422	6,184	11,606	1,569	16%
Phoenix	93,204	89,800	183,004	101,773	98,916	200,689	17,685	10%
Scottsdale	9,118	12,998	22,116	11,021	10,421	21,442	-674	-3%
Surprise	4,992	3,213	8,205	1,347	1,891	3,238	-4,967	-61%
Tempe	6,322	9,563	15,885	9,544	7,890	17,434	1,549	10%
All Others	4,841	3,460	8,301	2,762	3,152	5,914	-2,387	-29%
TOTAL	153,588	152,487	306,075	154,540	153,317	307,857	1,782	1%
* Includes class counts on arterials only								

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Forecasts

- Developed growth factors from TRANSEARCH forecasts for
    - » External station targets
    - » Special generators
    - » E-E flow tables

- Using forecast year NAICS2 data and growth factors, derived truck volumes for forecast years

- MAG currently using these truck forecasts for conformity analysis

Forecasts (contd)

- Total truck VMT any given year is approximately 33% of overall regional vehicular VMT

- On average, 69% light, 14% medium, 17% heavy (of total truck VMT)

Analysis Year	Light Truck VMT	Medium Truck VMT	Heavy Truck VMT	Total Regional Vehicular VMT
2008	22,683,088	5,327,839	6,227,615	104,225,099
2021	35,638,747	7,097,361	8,444,184	156,081,290
2025	39,432,576	7,499,675	9,015,529	170,612,517
2031	44,587,146	7,767,131	9,661,776	188,464,537
Annual Percent Rate	**3.0%**	**1.7%**	**1.9%**	**2.6%**

Future Model Improvements

- Collect freeway classification counts based on FHWA classes (expected in 2011)

- Use screenlines for trucks (developed in 2010)

- Acquire GPS data for trucks to (expected in 2011) –
    - » Update internal truck model
    - » Develop trip chaining model

- Use new TRANSEARCH data to update external truck model (acquired 2009 data)

- Use TRANSEARCH's STCC50 to identify 'secondary' traffic (to/from warehouses, DCs, IMXs, airports) (expected in 2011)