## Development of a Truck Model for Memphis

presented to

## Tennessee Model Users Group (TNMUG)

presented by
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## Outline

Why Truck Models?

Options for Memphis

- Development of External truck model

Development of Internal truck model

## 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;


## 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
- $\mathbf{3 5 \%}$ of the DVMTT are by trucks that carry FAF freight
- $65 \%$ of the truck DVMTT are by service (Non-FAF) trucks


## 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.


## External Truck Model

- Develop Estimation Databases
- Develop Commodity Groups

Develop Trip Generation Equations

- Develop Trip Distribution Equations


## External Estimation Database

Obtain and process TnDOT TRANSEARCH

- Window to Memphis MPO model boundary

1978.701
$\sim$ 4760.232-10127.985
$\sim_{10127.985-25881.729}$



## Commodity Groups

| Commodity Group <br> (CG) Name | CG \# | $\begin{gathered} \text { SCTGs in } \\ \text { CG } \end{gathered}$ | Daily Trucks Produced from I ( of IE) |  | Daily Trucks Attracted to l (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 | $\begin{gathered} \text { SCTG } 43 \& \\ \text { SCTG } 50 \end{gathered}$ | 1,859 | 48\% | 827 | 20\% |
| Total |  |  | 3,850 | 100\% | 4,068 | 100\% |
|  |  |  |  |  |  |  |

## 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


## 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 +
```


## 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 |

## 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 |
| 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 | 1,544 | 42 | 0.0173* | NA | 0.998 |

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


## I-E TAZ Productions (Memphis MPO)

## CG 7 Clay, Concrete, Glass



## I-E TAZ Productions

 (Tennessee)
## CG 7 Clay, Concrete and Glass



NAICS 327 Non-Metallic Mineral Manuf employees

$$
— \text { fit }--\mathrm{fit}+34 \%--\mathrm{fit}-34 \% \diamond \text { obs } \diamond \text { obs-sg }
$$

## I-E TAZ Productions

(Memphis MPO)

CG 10 Secondary \& Mixed Freight


$$
— \text { fit }--\mathrm{fit}+34 \%--\mathrm{fit}-34 \% \diamond \text { obs } \diamond \text { obs-sg }
$$

## E-I TAZ Attractions

## (Tennessee)

CG 10 Secondary and Mixed Freight


## 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 <br> (Memphis MPO)

## CG 1 Farm Products



## E-I TAZ Attractions

## (Tennessee)

## CG 1 Farm Products



## E-I TAZ Attractions

## (Memphis MPO)

## CG 3 Sand \& Gravel



## E-I TAZ Attractions

## (Tennessee)

## CG 3 Sand \& Gravel



## E-I TAZ Attractions

(Memphis MPO)

CG 10 Secondary \& Mixed Freight


$$
— \text { fit }--\mathrm{fit}+34 \%--\mathrm{fit}-34 \% \diamond \text { obs } \diamond \text { obs-sg }
$$

## E-I TAZ Truck Attractions

(Tennessee)

CG 10 Secondary \& Mixed Freight


## Exiernal 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

$$
T_{i j}=\frac{k_{i j} P_{i} A_{j} F_{i j}}{\sum_{j=1}^{n} k_{i j} A_{j} F_{i j}}
$$ interchanges

" "Friction Factor" is a negative exponential function of distance

- Coefficient is inverse of Average Trip Length (ATL)

$$
F_{i j}=e^{-c * d_{i j}}
$$

- ATL varies by CG
- Develop from Windowed TRANSEARCH
- Distance within region from network skim
- Distance outside of region as reported in windowed TRANSEARCH

$$
d_{i j}=d i_{i j}+d o_{i j}
$$

[^0]
## External Truck Model

## Trip Distribution Factors

| Commodity Group |  | Average Trip Length (miles) | Weighted Disfance (mi) <br> TS External Zones to <br> Memphis External Stations |  |
| :---: | :---: | :---: | :---: | :---: |
| Code | Name |  | -40,TN | 1-55, 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 |
|  |  |  |  | 26 |

## Inłernal 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 <br> 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


## Internal Model Trip Generation Rates

| QRFM Trucks |  |  | ATRI |  |
| :--- | :--- | :--- | :--- | :--- |
| Variable | Light | Medium | Heavy | TN SWM <br> TAZs |
|  |  |  |  | $\mathbf{R}^{2}=0.652$ |
| Agriculture, Mining and <br> Construction | 1.110 | 0.289 | $\mathbf{0 . 1 7 4}$ | $\mathbf{0 . 5 0 4}$ |
| Manufacturing, TCU and <br> Wholesale Trade <br> Retail Trade | 0.938 | 0.242 | $\mathbf{0 . 1 0 4}$ | $\mathbf{0 . 9 4 2}$ |
| Office and Services <br> Households | 0.888 | 0.253 | $\mathbf{0 . 0 6 5}$ | $\mathbf{0 . 7 8 4}$ |

## 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 $\mathbf{5 8 \%}$ of all CU truck trips


## Internal Model Trip Generation Rates

## Adjusted Rates trucks/day per employee (household)

| Variable | Light | Medium | Heavy |
| :--- | ---: | ---: | ---: |
| Agriculture, Mining and <br> Construction | 3.2152 | 0.8371 | 0.504 |
| Manufacturing, TCU and | 8.4961 | 2.1920 | 0.942 |
| Wholesale Trade | 10.7106 | 3.0516 | 0.784 |
| Retail Trade | 0.0049 | 0.0008 | 0.0001 |
| Office and Services | 0.0007 | 0.0003 | 0.0001 |

## Outliers from regression

- Outliers defined as those whose observed trips are more than +/-34 \% ( $1 / 2$ 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 Cenerator | 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 |

## Internal Truck Model Trip Generation

## ATRI II Ps and As TN SWM TAZs



## Internal Truck Model Trip Distribution Equations

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

$$
T_{i j}=\frac{k_{i j} P_{i} A_{j} F_{i j}}{\sum_{j=1}^{n} k_{i j} A_{j} F_{i j}}
$$ model

- "Observed" ATRI truck table

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 | $\mathbf{- 0 . 0 3}$ | $\mathbf{3 3 . 3} \mathbf{~ m i n}$ | $\mathbf{- 0 . 0 9 3}$ | $\mathbf{1 0 . 7} \mathrm{min}$ |

## 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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[^0]:    - Varies by CG and External Station

