Development of a Truck Model for Memphis

presented to

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Outline

- Why Truck Models?
- Options for Memphis
- Development of <u>External</u> truck model
- Development of <u>Internal</u> 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
 - 35% 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





Commodity Groups

| Commodity Group (CG) Name | CG # | SCTGs in CG | Daily Trucks Produced from I (of IE) | | Daily Trucks Attracted to I (of El) | |
|--------------------------------|------|----------------------|---|-------------|---|-------------|
| 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% | 99 0 | 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% |



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 | | | DO | |
|-----------------|--------------------------------|-------------------|-----------|-------------|--------|---------|-------|--|
| Code | Name | TRANSEARCH | Estimated | NAICS | Rate | t-Stat | K.Z | |
| 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 | | | DO |
|-----------------|--------------------------------|-------------------|-----------|-------------|---------|--------|-------|
| Code | Name | TRANSEARCH | Estimated | NAICS | Rate | t-Stat | KZ |
| 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 |





I-E TAZ Productions (Memphis MPO)

CG 7 Clay, Concrete, Glass





I-E TAZ Productions (Tennessee)

CG 7 Clay, Concrete and Glass







I-E TAZ Productions (Memphis MPO)

CG 10 Secondary & Mixed Freight





E-I TAZ Attractions (Tennessee)

CG 10 Secondary and Mixed Freight



E-I Truck Attraction Equations

| Commodity Group | | 2012 Trucks | | Variable | | | DO | |
|-----------------|--------------------------------|-------------|-----------|----------|--------|--------|-------|--|
| Code | Name | TRANSEARCH | Estimated | NAICS | Rate | t-Stat | κz | |
| 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 | Рор | 0.235 | 43.710 | 0.996 | |
| 4 | Gasoline & Fuel | 95,544 | 97,962 | Рор | 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 | Рор | 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)

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)







E-I TAZ Attractions (Memphis MPO)

CG 10 Secondary & Mixed Freight





E-I TAZ Truck Attractions (Tennessee)

CG 10 Secondary & Mixed Freight





External Ps and As

- Seed table is Windowed TRANSEARCH
- Row and column constraints are truck counts at External Stations
 - » <u>No</u> 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

$$T_{ij} = \frac{k_{ij}P_iA_jF_{ij}}{\sum_{j=1}^n k_{ij}A_jF_{ij}}$$

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

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



External Truck Model Trip Distribution Factors

| (| Commodity Group | Average Trip Length | Weighted Distance (mi) TS External Zones to Memphis External Stations | | |
|---|-----------------------------|------------------------|---|----------|--|
| Code | Name | (miles) | 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, Glass8 Durable Manuf | | 235 | 112 | 270 | |
| | | 589 | 310 | 456 | |
| 9 Waste | | 319 | 233 | 336 | |
| 10 | Secondary and Mixed Freight | 406 | 284 | 505 | |



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



Internal Model Trip Generation Rates

| QRF | ATRI trucks | | | |
|---|----------------|-------|-------|-----------------------|
| Variable | 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 |



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





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 |





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 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 |



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 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

 $T_{ij} = \frac{k_{ij}P_iA_jF_{ij}}{\sum_{i=1}^n k_{ii}A_iF_{ii}}$







Internal Truck Model Friction Factor Coefficients

| Q | RFM Truc | 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 |



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? Email:dbeagan@camsys.com



