# Estimating the Monetary Benefits of Reducing Delays on Heavily Trafficked Truck Freight Corridors in Georgia

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## *Task 2: Generating a Matrix of Origin-Destination-Commodity-Truck Class (O-D-C-V) Flows based on Location Specific Economic Activity Data.*

### 1. Introduction

This Technical Memorandum describes the process of constructing a set of truck traffic flows for a major Interstate Highway corridor. The case study corridor selected for empirical analysis is the I-85/I-285 corridor through the state of Georgia (see Task 1 Technical Memorandum). The technical challenge involves creating a set of truck based commodity flow matrices at a level of spatial disaggregation suitable for corridor planning purposes, including the ability to assign such flows to state's highway network, and doing this from existing datasets. Increased interest in both inter-city and inter-state corridor-level freight movement patterns, as reflected in the federal government's MAP-21 legislation, has added renewed significance to such data modeling efforts (FHWA, 2013).

The need to "model" existing freight movement data stems from the limited amount of spatially detailed commodity or truck flow data below the very broad regional level once analysis moves beyond a single metropolitan area. A recent review of past efforts to create, and also forecast, spatially detailed truck-based commodity flow matrices by Southworth (2014) identifies a number of different approaches to the problem, depending on both study purpose and resources. The 26 studies listed in the report run the gamut from simple factoring of regional commodity production, consumption, or production-consumption totals on the basis of industrial sector employment and population, to various types of regression analysis linking reported regional tons or dollars of freight shipped to regional measures of industrial activity, population size and land use (with subsequent use of these equations at a more detailed level of geography), to more elaborate direct and indirect effects based structural equations modeling, to the use of inter-industry input-output tables linked to spatial interaction models that associate one industry's production or consumption, initially in dollar terms, with the inputs and outputs of other industries within or outside a region. None of these approaches proves to be entirely satisfactory, and a fifth, highly data intensive line of development is sometimes required to construct freight movements for data that is to some degree unique to specific commodity classes (notably agricultural and energy commodities). Within the United States each of these modeling options usually involves adjusting the resulting origination-to-destination commodity flow ("O-D-C") totals to fit those reported by the Federal Highway Administration's (FHWA) Freight Analysis Framework (FAF) data and modeling program (FHWA, 2014). Most of these modeling exercises have two major steps: 1) estimate the volume of freight a) produced and b) consumed within a region (e.g. a county), and 2) estimate the flows between all pairs of regions. In transportation planning terminology, this refers to trip generation and attraction modeling, followed by trip distribution modeling. In all cases, the result of this freight modeling process is a *synthetic matrix* of county-or sub-county based, origin-destination-commodity flows, usually for a given calendar year. These commodity flows are then converted to truck trips, based on data sources that tie specific types and sizes of trucks and their cargo load factors, to specific commodity or industry classes.

The rest of this technical memorandum describes the method used to construct a set of county and sub-county level commodity flow matrices and their conversion to truck trips. The commodity classes used are the 43 classes used by the latest available (2007) U.S. Commodity Flow Survey and its expanded coverage to non-CFS surveyed industries as captured by the latest (also 2007) Freight Analysis Framework dataset (FAF Version 3, or FAF3): see Table 2.1. These truck trip matrices are themselves disaggregated according to five truck size classes (see below) for use in both O-D-C travel cost modeling and subsequent network traffic assignment (as described in this project's Task 3 Technical Memorandum).

**Table 2.1 FAF3 2-Digit SCTG* Commodity Classes**

| SCTG | Commodity | SCTG | Commodity | SCTG | Commodity |
|---|---|---|---|---|---|
| **01** | Live animals/fish | **15** | Coal | **29** | Printed products |
| **02** | Cereal grains | **16** | Crude petroleum | **30** | Textiles/leather |
| **03** | Other agricultural products. | **17** | Gasoline | **31** | Nonmetal mineral products |
| **04** | Animal feed | **18** | Fuel oils | **32** | Base metals |
| **05** | Meat/seafood | **19** | Natural gas and petroleum prods. | **33** | Articles-base metal |
| **06** | Milled grain prods. | **20** | Basic chemicals | **34** | Machinery |
| **07** | Other foodstuffs | **21** | Pharmaceuticals | **35** | Electronics |
| **08** | Alcoholic beverages | **22** | Fertilizers | **36** | Motorized vehicles |
| **09** | Tobacco prods. | **23** | Chemical prods. | **37** | Transport equipment |
| **10** | Building stone | **24** | Plastics/rubber | **38** | Precision instruments |
| **11** | Natural sands | **25** | Logs | **39** | Furniture |
| **12** | Gravel | | Wood products | **40** | Misc. mfg. products. |
| **13** | Nonmetallic minerals | **27** | Newsprint/paper | **41** | Waste/scrap |
| **14** | Metallic ores | | Paper articles | **43** | Mixed freight |
| | | | | **99** | Commodity unknown |

* Standard Classification of Transported Goods

## 2. Study Corridor Definition

Figure 2.1 shows the study corridor in national context. Truck flows within and through the corridor are modeled using a three-tier spatial disaggregation process.

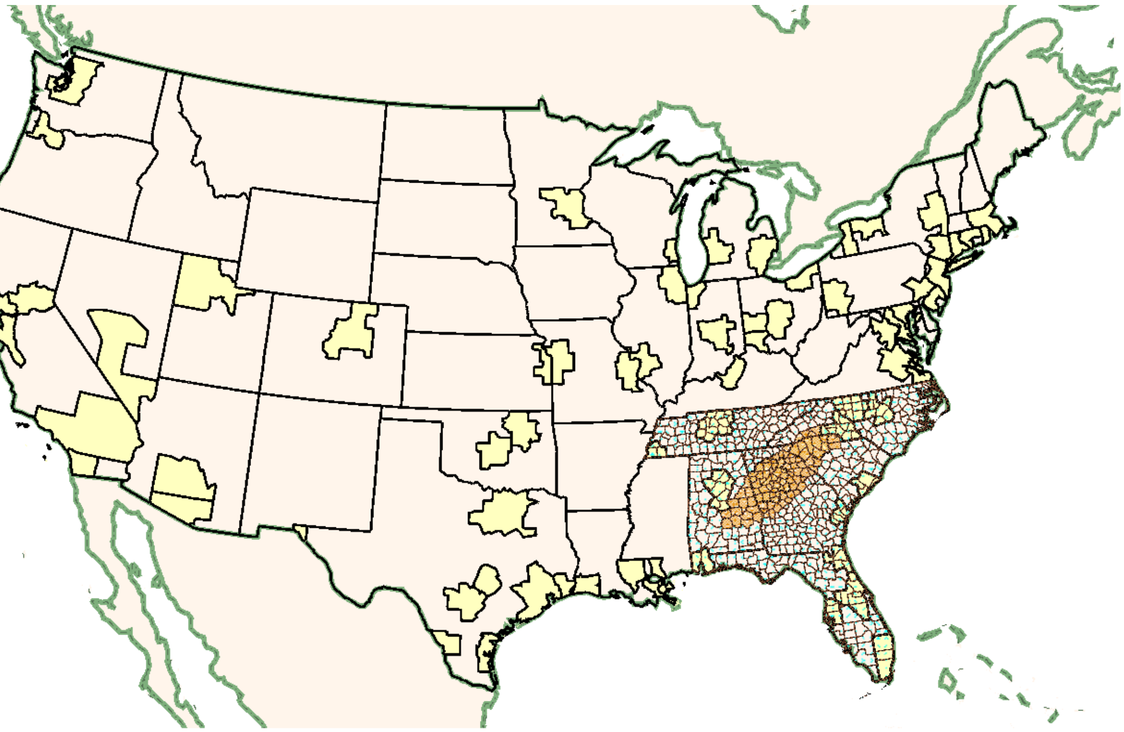

**Figure 2.1 Corridor Study Area, National Context: Tier 1 and 2 Traffic Analysis Regions**

Tier 1 provides nationwide coverage (including import and export flows through the nation's ports and border crossings) and is represented by the 123 internal to the U.S. FAF3 regions or regional analysis zones. These include 74 metropolitan area regions (shown in yellow in Figure 1), 33 regions made up of state remainders which represent a state's territory outside these metropolitan regions, and 16 regions identified as entire states within which no FAF3 metropolitan regions exist (Southworth et al, 2011).

Based on study of FAF3 inter-regional truck freight movement data, a six state region surrounding the corridor was selected for Tier 2, county level disaggregation. Figure 2 shows this six state south-eastern region (i.e. Alabama, Florida, Georgia, North and South Carolina and Tennessee), showing the region's counties and also its interstate highway system. This six state south-eastern region containing 21 FAF3 regions, including 15 FAF3 metropolitan regions and 6 state remainders, for a total of 534 south-eastern region counties.

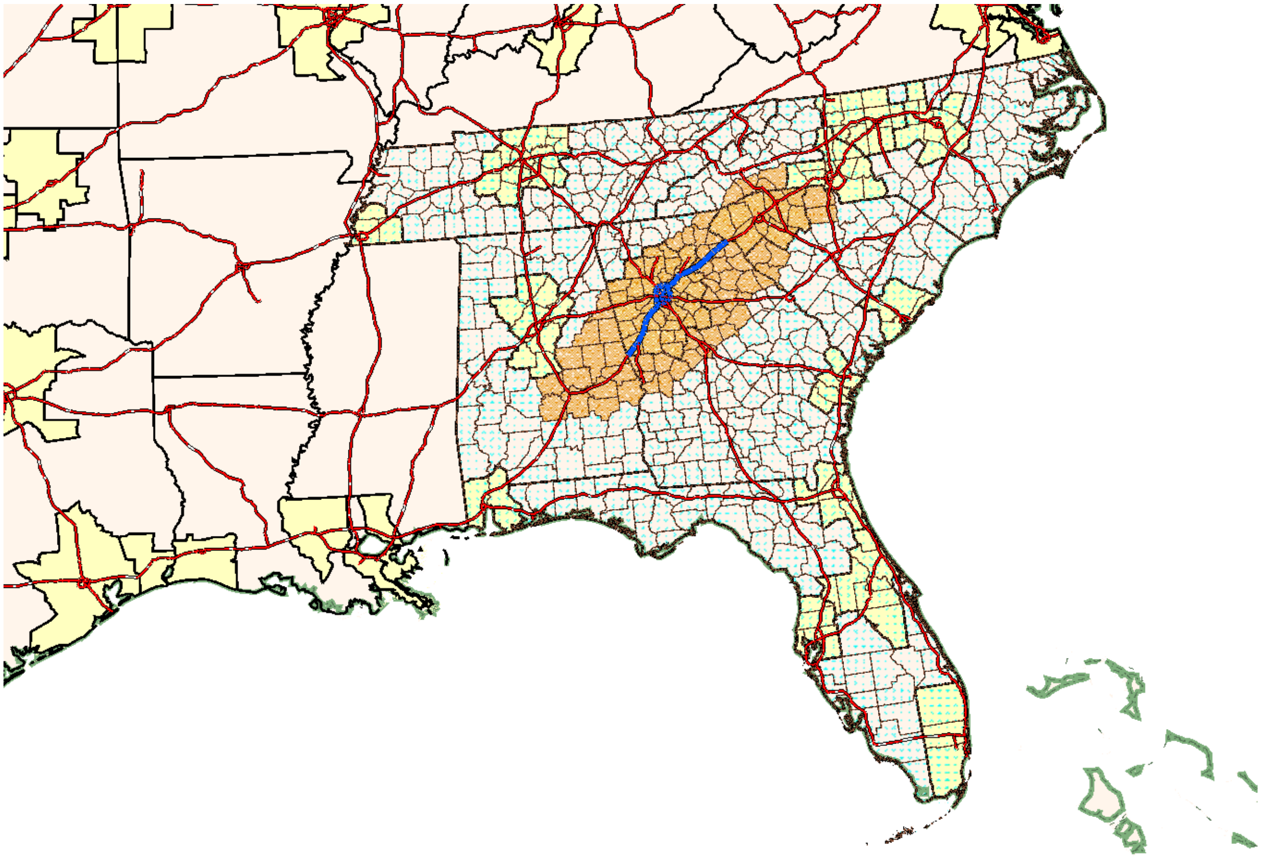

**Figure 2.2 The Six State Southeastern Region's Counties and Interstate Highways**

Tier 3 disaggregation then involved breaking down flows within selected counties adjacent to the I-85/I-285 highway (counties represented by the brown shading in Figure 2.2), where additional spatial detail was deemed important to an effective traffic-to-highway route specific assignment solution.

## 3. Defining Internal and External Trips: Tier 1 Disaggregations

Commodity flow origins and destinations outside the corridor's six state southeastern region are based on FAF3 regions and termed external trip ends and trips that both begin and end outside this region are termed external-external (E-E) flows (of which there are a potential 102 x 102 flows for each commodity class). These flows are not disaggregated and remain entirely Tier 1 flows. Commodity flows the start outside the region and end up within one of the 534 counties internal to the region are termed external-internal (E-I) flows, and those flows that begin within the region and end up outside it are termed internal-external (I-E) flows. There are therefore potentially 102*534 and 534*102 E-I and I-E flows, for each commodity transported. The actual number of these flows is much less, of course. These two flow sets also combine Tier 1 and Tier 2 levels of spatial (dis)aggregation. Finally, there are a potential 534 x 534 internal-internal (I-I) inter-county, disaggregated Tier 2 level flows. This was the level of disaggregation used to identify the most important O-D flow pairs using the corridor, including those diads that might benefit from further spatial disaggregation.

## 4. Tier 2 (County Level) Disaggregation Method

A number of different spatial disaggregation methods were experimented with in order to assign FAF3 commodity O-D flow totals to within-region county pairs, or diads. A two-step process was followed. Step 1 involved the estimation of county level commodity productions (= originations, or Os) and attractions (= destinations, or Ds). Step 2 then estimates the flows between these O-D pairs of counties.

### 4.1 County Level Production (Supply)

***Industries Covered by the U.S. Commodity Flow Surveys***

The majority of commodity production estimates were derived using US Commodity Flow Survey (CFS) tables. These tables cross-tabulate the 43 SCTG commodities reported in the 2007 CFS against the industrial sector breakdowns used by the North American Industry Classification System (NAICS). That is, these NAICs industries are the ones producing the SCTG-classified commodity flows reported by the CFS. In particular, Table 12[1] provides 2007 estimates of shipped tons, dollar trades, and ton-miles transported by CFS (also =FAF3) freight generation region, cross-classified by 2-digit SCTG and from 2-to-6-digit NAICS, depending on specific commodity class. Using this data, FAF3 truck freight productions (tons) were shared (i.e. disaggregated) across each FAF region's counties using U.S. Census reported County Business Patterns (CBP) data on annual employment and payroll dollars in each NAICS-specific industry (U.S. Census Bureau, 2014), i.e.

$$T(i,C) = \sum_{g \varepsilon G(C)} T(F,C,g) * \left[ E(i,g) / \sum_{i \varepsilon F} E(i,g) \right] \quad (2.1)$$

where T(i,C) = estimated tons of commodity c originating in county i.
T(F,C,g) = annual tons of commodity c shipped out of CFS (= FAF3) region F by industry g;
E(i,g) = total annual employment or payroll dollars associated with industry g in county i.

This approach, however, does not work for industries not included in the shipper establishment-based CFS (and referred to in the FAF3 documentation as "out-of-scope" or OOS industries). This includes farm-based and utility-based commodity flows, while the CBP dataset also

[1] http://apps.bts.gov/publications/commodity_flow_survey/2007/metropolitan_areas/remainder_of_hawaii/html/table_12.html

excludes NAICS industries involved in crop and animal production. Equation (2.1) is also not a reliable method for estimating some energy commodities, notably coal shipments, whose freight tonnages are not easily tied to employment or payroll totals, and which are usually associated with a limited number of (fortunately well documented) coal mining and electric utility sites. This led to the following approaches to disaggregating these various commodity classes.

***FAF3 Out of Scope Industries***

The following industries were not part of the 2007 CFS, and therefore required an appropriate allocation to their respective SCTG commodity classes prior to disaggregating FAF3 regional commodity production totals:

1. Farm Based
2. Fishery
3. Logging
4. Construction
5. Services
6. Retail
7. Household and Business Moves
8. Municipal Solid Waste
9. Crude Petroleum
10. Natural Gas Products

For spatial disaggregation purposes these industries are either largely one commodity based, and if captured by the CBP data are therefore easily distributed across counties: or they produce commodities that span more than one 2-digit SCTG class, and therefore require a sharing of their output across these commodities. The following paragraphs describe how each industry was treated in this study.

*Farm-Based Agricultural Commodities and Fisheries*

Farm-based agricultural commodity flows are not reported by either the CFS or CBP datasets. Spatial disaggregation was accomplished using county-level farm production data from the 2007 Census of Agriculture, with data drawn from USDA's Desktop Query Tool version 1.2 (USDA, 2009). This production data is reported as number of animals sold and either crop sales or crop acres harvested. This data was then converted (e.g. from bushels, bales, weight per animal) to kilotons, using the per unit weight conversions for specific crops and types of livestock published by the USDA (see USDA 1992).[2] Livestock sales within a county (composed of cattle

[2] In some cases a direct conversion to commodity specific tons was not readily available. For example, milk production was estimated as the number of milk cows in a county multiplied by the average milk yield per cow for that state. The tons of fruits and nuts shipped was based on a

and calves, broiler and other meat-type chickens, layers, pullets and eggs, turkeys, pigs and piglets, sheep and lambs, goats, and horses and ponies sold) were derived and assigned to SCTG1, while grain crops (including barley, corn, oats, rice, rye, sorghum and wheat) were assigned to SCTG2 and vegetables, fruits and nuts and other farm crops, including beans, cotton, peanuts, soybeans, sugar cane, sugar beets, and tobacco, were assigned to SCTG3. Raw milk production was assigned to SCTG4. Fish are reported under NAICS category 114 (fishing, hunting and trapping) in the CBP.

*<u>Construction, Household and Business Moves, Retail, and Service Industry Commodities</u>*

Commodities produced by industries in NAICS categories 23 (Construction), 44 (Retail), 52 (Services) and 4842 (Specialized Freight Trucking) were distributed on the basis of BEA's 2007 industry–to-commodity make tables. Figure 2.3 below (taken from Southworth et al, 2011) shows the principle NAICS to SCTG relationships involved.

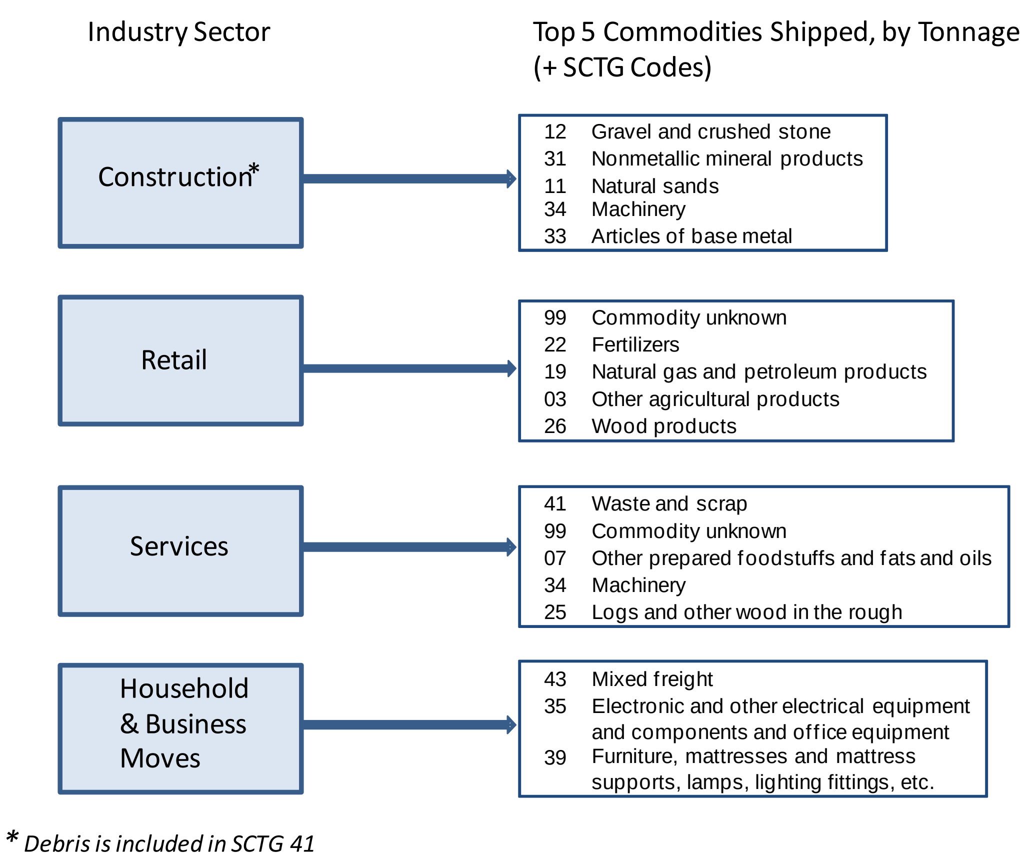


**Figure 2.3 Principal Commodities Shipped by Tonnage in Four Industrial Sectors**

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county's farm acreage in citrus fruit, non-citrus fruit, and nuts multiplied by the average yield per acre for each of these three commodity sub-classes.

*Logging*

Logging products (SCTG 25) were allocated on the basis of county employment activity in NAICS category 113.

*Municipal Solid Waste*

Municipal Solid Waste (MSW)[3] presents something of unique challenge. It does not have a specific code in NAICS. Its production was shared to counties on the basis of a county's employment in durable and non-durable goods, construction, retail and service industries, making use of the allocations to waste and scrap derived for each of these other industry classes.

*Crude Petroleum and Natural Gas*

County allocations of FAF3 regional production totals were based on employment in NAICS class 211111 – 'Crude Petroleum and Natural Gas Extraction.'

*Coal*

The amount of coal mined and shipped does not correlate well with either employment or payroll data, and its spatial disaggregation was therefore treated separately. There was a limited amount of coal production in the six state south-eastern region in 2007, most of it concentrated in just 10 Alabama and 3 Tennessee counties. Fortunately also, data sources on the coal industry are among the best reported commodities. Annual coal plant production data for these counties, reported in kilotons, was created from individual coal plant data reported by the Energy Information Administration (EIA, 2014). To this data were added FAF3 seaport region-specific imports, extracting only those moved inland by truck. Over 94% of these within- region shipments came in through the five ports Charleston SC, Jacksonville and Tampa FL, Mobile AL, Savannah GA, with a small volume also entering through the port district covering the Remainder of North Carolina: a result found to be consistent with the EIA's 'Monthly Report IM 145' data series for 2007. This combined production and import data was then used to share internal coal originating shipment volumes across study area counties in a manner that matched the volumes reported by FAF3 truck shipments

## 4.2 County Level Freight Consumption (Demand)

County specific freight attractions pose a more difficult problem than productions, largely because the CFS is a shipper-at-origin based survey, and because the number of either raw or intermediate product inputs into many industrial processes is typically much larger than the number of products coming out of a particular industry. This is where an input-output (I-O)

[3]MSW includes: containers and packaging, such as soft drink bottles and cardboard boxes; durable goods, such as furniture and appliances; nondurable goods, such as newspapers, trash bags, and clothing; and other wastes, such as food scraps and yard trimmings.

based approach offers the considerable advantage of being able to link such, often diverse, commodity inputs to industry outputs. This includes the assignment of final product sales (and hence trades) to U.S. households, government agencies, and foreign exports (see Miller and Blair, 2009, for example). County and commodity class-specific shipment destinations were estimated in this project using the Bureau of Economic Analysis' (BEA) 2007 national commodity-to-industry "Use" table to first of all associate specific commodity classes with the industries that make use of (i.e. that purchase) them. Specifically, if we let V(C,g) refer to the dollar value of commodity C used in industry g, then:

$$U(C,g) = V(C,g)/\Sigma_C V(C,g) \qquad (2.2)$$

which = the share of commodity C used in the total ($ valued) output of industry g. With this we then compute:

$$T(C,j) = T(C,F) * \{\sum_{g\varepsilon G(C)} U(C,g) * [ E(j,g)/ \sum_{j\varepsilon F} E(j,g) ]\} \qquad (2.3)$$

where T(C,j), T(C,F) = the tons of commodity C destined for county j and for FAF region F, respectively, E(j,g) = the annual employment in industry g in county j receiving commodity C; and the summation in equation (2.3) is over all industries that consume commodity C.

In words, and working backwards from right to left, equation (2.3) combines two share computations, one spatial and the other industry sector-based. First it computes the share of industry g's activity, represented by its employment, found in county j. Then it multiplies this share by the share of commodity C produced by industry g, repeated and summed over all g=1,2,.. industries that use commodity C in county j. Finally, this result is then factored to sum to the volume (tons) of C delivered to FAF3 region F by truck.

The major drawbacks of this and other, similar I-O approaches are due to a) the limited spatial disaggregation in current I-O tables (which average over some potentially significant regional differences in product composition and productivity) and the rather crude breakdown of "commodities" within the national I-O accounts, with limited detail available within many industrial sectors. For forecasting purposes, the essentially static nature of the I-O tables also represents a third limitation. This said, the approach has seen a good deal of use for freight flow modeling over the past two decades, both within the U.S. and abroad, because of its ability to tie the supply side of commodity flow to the demands for goods as both intermediate and final products within industry supply chains.

Note that this dollar based commodity-to-industry translation can be turned back into both commodity-specific dollars and also into tons shipped using CFS average $/ton statistics, while annual payroll dollars spent in industry g in each county can also be used to share the commodities involved across counties. Note also that by using the FAF truck specific volumes T(C,F) in equation (2.3) there is an implicit assumption that all counties get a share of this trucking activity irrespective of whether or not they may contain a rail or water option to move certain commodities that ought to limit their use of truck. The national Use table used in the disaggregations was the six-digit NAICS-based "IOUse_After_Redefinitions_2007 Producer Value" table, drawn from the 2007 benchmark national Input-Output accounts released on December 18, 2013 (BEA, 2014). This table allowed re-aggregations of 377 detailed NAICS industrial classes into the 43, 2-digit SCTG commodity classes used in the freight flow modeling.

*Coal*

To obtain the likely destination county for coal shipments, a surrogate for annual coal delivery data was obtained from the Environmental Protection Agency's (EPA) eGrid website, in the form of utility plant-specific and coal-based net electricity generation, reported in megawatt-hours, or MWh (EPA, 2014). According to FAF3, coal exports resulting from truck trips into a port county were limited in 2007, principally through Mobile AL, with a small volume also passing through Miami FL. FAF3 regional coal truck freight destination totals were then shared to these utility plant-located counties using the MWh data, again rectified to match FAF3 intra-regional truck destination totals. The most likely error introduced by this method is the assumption that truck mode shares are similar across within-region counties.

### 4.3 Inter-County (O-D) Commodity Flows

The simplest method for creating a set of inter-zonal flows, given a set of county specific Os and Ds, is to share these flows between all zones within each pair of FAF O-D regions. This is done on the basis of the relative cross-product of each county's O and D volumes, with the results then reconciled back to the FAF region-to-region O-D flow totals, i.e. for each commodity, C in turn, we compute:

$$T(i,j) = FAF(I,J) * [\ O(i) / OFAF(i) \quad * \quad D(j) / DFAF(j)] \qquad (2.4)$$

where T(i,j) = the annual tons of the commodity being flowed moving between counties i and j; $O_i$ = county i production (originations), $D_j$ = county j attraction (destinations), and OFAF(i) and DFAF(j) = the county aggregated FAF3 regional activity totals for the commodity being flowed, computed as:

$$OFAF(i) = \sum_{i\varepsilon I} O(i) \qquad \text{and} \qquad DFAF(j) = \sum_{j\varepsilon J} D(j) \qquad (2.5)$$

This approach allows full advantage to be taken of the FAF3 inter-regional O-D flows as suitable control totals. It does not, however, recognize the potential effects of additional, notably distance-based transportation costs on these interaction patterns. This effect is usually captured by a series of commodity specific spatial interaction (SIA) or "gravity" models. This was the second approach tried, by applying the following general SIA formula to each commodity in turn:

$$T(i,j) = O(i) * D(j) * G[Cost(i,j)] * A(i) * B(j) \qquad (2.6)$$

where the A(i) and B(j) terms are the usual iteratively derived balancing factors used in doubly constrained spatial interaction models (Wilson, 1970)[4]; where G[Cost(i,j)] = a function of marginal cost of inter-county transportation; and where each i-to-j cost element is itself a multi-component function of the form:

$$\text{Transportation Cost} = \alpha 1 * \text{Money} + \alpha 2 * \text{Travel Time} + \alpha 3 * \text{Travel Time Reliability} \qquad (2.7)$$

for a set of model calibrated cost sensitivity parameters α1 – α3, and where "Money" costs in equation (2.6) is broken down as follows (see Torrey and Murray, 2014):

$$\text{Money} = \text{Labor Costs (mainly Driver wages and benefits)} + \text{Vehicle O\&M Costs} \qquad (2.8)$$

and where O&M refers here to the marginal (per mile or per hour) costs of vehicle operation and maintenance, including fuel costs, vehicle repair, maintenance and insurance costs, lease or purchase payments, permits and licenses, and tolls.

Of particular interest to the present study are the travel time and travel time reliability components referred to in equation (2.7). While measurement of travel time is relatively straight-forward, measuring travel time (un)reliability is more challenging, but usually involves some assessment of the day-to-day variability in journey times over a suitable period (such as over a travel season, or a typical weekday). The α2 and α3 parameters in equation (2.8) represent the importance placed on these value of travel time and value of travel time unreliability terms and offer a means of quantifying the costs of, respectively, additional travel time and travel time disruption. This measurement issue is addressed in Task 4 of the project.

### 4.4 Tier 3 (Within County) Disaggregation Method

The effects of further spatial disaggregation of freight productions and attractions was examined by further partitioning the origination and destination locations of the corridor's largest inter-county based O-D-C flows. At issue is whether and how such a disaggregation influences the subsequent assignment of commodity-cum-truck trips to corridor links (a result to be determined in Task 3 of the project). This disaggregation process makes use of a commercially supplied set of geo-locations tied to the U.S. Census Bureau's ZIP Code Business Patterns dataset ("ZBP data") for 2007 (U.S. Census Bureau, 2014).

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[4] i.e. $A(i) = 1/\sum_j B(j).D(j).G[Cost(i,j)]$ for all i; and $B(j) = 1/\sum_i A(i)O(i).G(Cos(i,j)]$ for all j.

Examination of this ZBP dataset found many missing or suppressed data items. Given the effort required to fill such gaps a method was sought for selecting a subset of those counties involved in the corridor's major O-D-C flows. To assist with this selection process it was decided to first of all assign the county-level O-D-C flow estimates to the I-85/I-285 corridor links (a Task 3 activity) and to defer this Tier 3 disaggregation until such assignments were completed. The idea here is to be as cost-efficient as possible in the tasks of database construction as well as application, without losing important information in the process.

## 5. Conversion of Commodity Tons Shipped to Daily and Peak-Period Truck Trips

Commodity tons shipped estimates were converted into number of truck trips, spread across five different truck size and configuration categories: single unit, truck with trailer, combination semi-trailer, double trailer, and triple trailer combinations. Following the methodology described in Battelle (2011), as applied in FAF3, commodity flows were also shared across nine truck body types as well as five distance ranges. Figure 2.4 shows the steps involved.

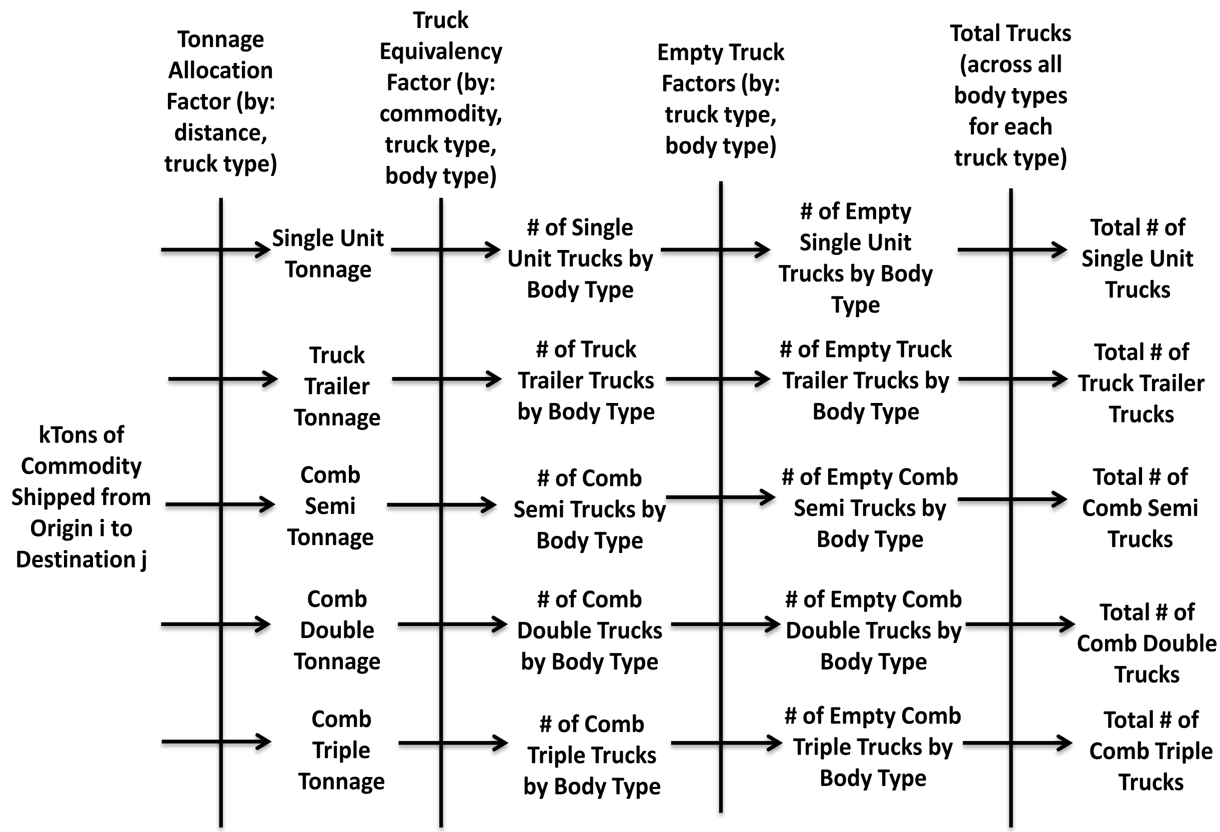


**Figure 2.4 Steps in the Tons to Trucks Procedure**

First, use the factors reported by Battelle to distribute each commodity's O-D tons based on truck size class and O-D shipment distance interval. Next, convert these tonnage shares into the number of trucks in each size class, also introducing a vehicle's body type into the process here to capture appropriate vehicle load factors. Up to nine body types are defined for each truck size class in the Battelle table. These body types are: *auto, livestock*, *bulk*, *flatbed, tank*, *dry van, reefer, logging and other*. Next, add in a factor for empty truck movements differentiated by both truck size class and body type. Finally, sum across all body types to get the number of truck trips per O-D-commodity flow in each of the five vehicle size classes.

In the first step of this process, five distance intervals are used to capture the differing probability of a truck of a given type (size class) making deliveries at different distances from its origination point. The five distance intervals used to capture this important effect are less than 51 miles, 51 to 100 miles, 101 to 200 miles, 201 to 500 miles, and more than 500 miles. At this point the result remains in commodity specific tons shipped by vehicle type. The truck equivalency factors used to relate these commodity tons to number of truck in size class 'v' is then computed as:

$$Y_v = \sum_{k=1}^{k=9} \frac{X_{Cv} \beta_{Cvk}}{\omega_{Cvk}} \tag{2.9}$$

where,
$Y_v$= number of trucks of truck type v
$X_{Cv}$ = tons of commodity C moved by truck type v
$\beta_{Cvk}$ = the proportion of commodity C moved by truck type v with body type k
$\omega_{Cvk}$ = the average payload of truck type v with body type k transporting commodity C

The empty truck loading factors are meant to capture the proportion of trips in a vehicle category that engage in empty back-hauls and empty vehicle repositioning legs, and take the form:

$$E_v = \sum_{k=1}^{k=9} \frac{X_{Cv} \beta_{Cvk} E_{vk}}{\omega_{Cvk}} \tag{2.10}$$

where,
$E_v$ = number of empty trucks of truck type v
$X_{Cj}$ = tons of commodity C moved by truck type v
$\beta_{Cvk}$ = the percent of commodity C moved by truck type v with body type k
$\omega_{Cvk}$ = the average payload of truck type v with body type k transporting commodity C
$E_{jk}$ = empty truck factor for truck type v with body type k

Total truck trips of type v assigned to a specific O-D-commodity flow are then computed as:

$$Y_v + E_v \quad (2.11)$$

where,
$Y_v$ = number of payload carrying trucks of truck type v
$E_v$ = number of empty trucks of truck type v

For further details of this multi-step ton-to-truck conversion procedure, see Battelle (2011), which can be downloaded from FHWA's FAF3 website. The report also contains the many conversion tables required to produce these commodity-and-distance determined truck traffic estimates. Of note, the various truck distance interval, payload, and empty truck trip factors derived and reported in the tables published in Battelle are based on data from the U.S. Census Bureau's 2002 Vehicle Inventory and Survey (Census, 2004). With the loss of the VIUS data collection program since that time, an update to these conversion factors is clearly needed at the present time. The FAF3 procedure was used because it represents the most detailed and fully documented procedure of its type to date, and because it offers consistency with the use of FAF3 dataset as a source for example network traffic loadings.

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