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ANALYSIS OF COMMODITY FLOWS AT A COUNTY LEVEL

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Abstract

This study presents a method for the development of an origin-destination trip matrix describing commodity flows by truck at the county level. Commodity flows analyzed are those from selected Counties to U.S. States, from U.S. States to selected Counties, and from selected Counties to selected Counties. The trip table is developed from several data sources and a combination of numerical methods and probabilistic analysis. A simplified application is presented to illustrate the proposed methodology. The reduced size of the hypothetical network results in an easily understood example application. A schematic representation of the methodology provides a visual outline of the procedure, which is described in detail through an application to the development of an origin-destination trip matrix of commodity flow in Pennsylvania. This application of the proposed method provides significant information on the amount and direction of commodity flow into and out of Pennsylvania Counties.

ANALYSIS OF COMMODITY FLOWS AT A COUNTY LEVEL

INTRODUCTION

The purpose of this study is to develop a method for analyzing commodity flows by truck at the county level. The final output of this analysis is an Origin-Destination Trip Matrix of Commodity flows. Several Federal databases are available with information related to State freight movements, including the *1993 to 1994 Surface Transborder Freight* and the *1993 Commodity Flow Survey (CFS).* In addition, there are privately developed databases with more detailed information on commodity flows. These databases are often very expensive to purchase and complex to understand. The objective of this study was to develop a method which will use data readily available from federal sources to determine commodity flows at a county level.

Development of a trip table requires the integration of numerous data sources and the development of procedures to manipulate the available data. This study analyzes three distinct origin-destination commodity flow groupings: state to county, county to state, and county to county. The state to county flow is based on a county household-percentage distribution technique while county to state flow is based on a county employment percentage algorithm. These two distribution techniques are used to determine the productions and attractions for each county, which are respectively equal to commodity flow origins and destinations. Distribution of county to county flow is accomplished with a gravity model application. Finally, commodity flows by truck in thousands of tons per year are synthesized into one large table- the Origin - Destination Trip Matrix. Many of the analysis procedures and techniques used are detailed in the *Quick Response Freight Manual* (QRFM, 1996).

The Origin-Destination Matrix (Trip Table) can be used as input in an assignment model which will determine commodity flows over the truck routes within an analysis area. Model and methodological accuracy can be estimated, as sample data from various weigh stations and checkpoints is available.

The remaining discussion proceeds as follows. Section 2 presents a simple example application. Section 3 presents an outline and a graphical representation of the proposed method. Section 4 presents a comprehensive discussion of the proposed method through its application to a case study. Section 5 presents concluding remarks.

EXAMPLE COMMODITY FLOW PROBLEM

The following example illustrates the process necessary for the development of an Origin-Destination commodity flow matrix. The reduced size of the experimental network results in an easily understood example application. The map presented in Figure 1 displays five bordering geographic regions GR-1, GR-2, GR-3, and GR-4 that are comparable to states bordering the state of interest, GR-5. GR-5, unlabeled, is divided into four sub-regions; SR-1, SR-2, SR-3 and SR-4. These smaller geographical entities are comparable to counties within the state of interest.

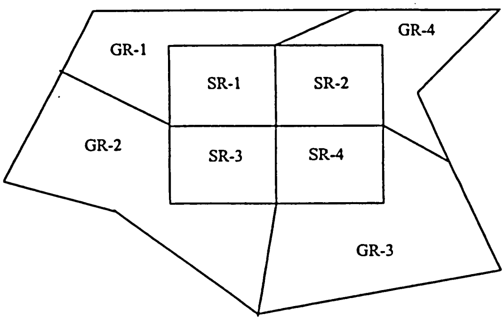


Figure 1: Example Geographic Area

Suppose data, describing commodity flow between geographic regions can be exported from a larger database. This data, shown in Table 1, indicates the flow of commodities (in tons per year) into GR-5, by truck from the surrounding geographical regions. That is GR-5 is the destination of commodity flow moving by truck from the origins GR-1, GR-2, GR-3 and GR-4.

Table 1: Commodity Flow (in tons per year) Moving by Truck into GR-5

Origin	Destination GR-5
GR-1	1000
GR-2	500
GR-3	750
GR-4	200
GR-5	600

It is assumed that commodity consumption is proportional to population density, meaning that it will occur equally for all households; therefore the total commodity destined for GR-5 is distributed to each SR based on the percent of households in GR-5 that each SR contains. These percentages are 25%, 30%, 15%, and 30% for SR-1, SR-2, SR-3 and SR-4 respectively. The flow distribution to GR-5 (destination) by household percentage is shown in Table 2.

Table 2: Distribution of commodity flow from GR-1 through GR-4 to SR-1 through SR-4

Origin	Destination (% of households)			
(Weight in tons/yr.)	SR-1 (25%)	SR-2 (30%)	SR-3 (15%)	SR-4 (30%)
GR-1 (1000)	250	300	150	300
GR-2 (500)	125	150	75	150
GR-3 (750)	188	225	112	225
GR-4 (200)	50	60	30	60

Commodities originating in GR-5 flow to all surrounding geographical regions. That is GR-5 is an origin and GR-1, GR-2, GR-3 and GR-4 are all destinations. Suppose that the weight, in tons per year moving by truck, of commodities originating in GR-5 can be extracted from an available data source. It can be assumed that each sub-region is responsible for producing a proportional percentage of commodity groups based on the percentage of employment of the industry, representative of this commodity group, in the sub-region. Table 3 and Table 4 display the flow of two commodity groups from GR-5 to all other geographical regions (GR-1, GR-2, GR-3, GR- 4).

Table 3 Flow of Commodity Group 1 from GR-5 to Surrounding Areas (in tons per year)

	Destination				
Origin	GR-1	GR-2	GR-3	GR-4	GR-5
GR-5	1000	2000	300	750	400

Table 4 Flow of Commodity Group 2 from GR-5 to Surrounding Areas (in tons per year)

	Destination				
Origin	GR-1	GR-2	GR-3	GR-4	GR-5
GR-5	750	200	1000	1000	200

Notice that GR-5 appears both as an origin and a destination. The sum of the GR-5 to GR-5 Origin-Destination pairing (in Table 3 and Table 4) is necessary for the analysis of inter-sub-region flow. The flows displayed in Table 3 and Table 4 can now be back distributed to SR-1, SR-2, SR-3 and SR-4, according to the percentage of employment in industry group 1 or industry group 2 respectively within each sub-region. The resulting distributed flow of commodity group 1 is shown in Table 5 and the distributed flow of commodity group 2 is shown in Table 6.

Table 5: Distribution of Commodity Group 1 to GR-1 through GR-4

	Destination (Weight in tons per year)			
Origin (Employment %)	GR-1 (1000)	GR-2 (2000)	GR-3 (300)	GR-4 (750)
SR-1 (50%)	500	1000	150	375
SR-2 (10%)	100	200	30	75
SR-3 (25%)	250	500	75	188
SR-4 (15%)	150	300	45	112

Table 6: Distribution of Commodity Group 2 to GR-1 through GR-4

	Destination (Weight in tons per year)			
Origin (Employment %)	GR-1 (750)	GR-2 (200)	GR-3 (1000)	GR-4 (1000)
SR-1 (25%)	188	50	250	250
SR-2 (15%)	112	30	150	150
SR-3 (45%)	338	90	450	450
SR-4 (15%)	112	30	150	150

Information concerning employment characteristics on a county level is obtainable from a variety of data sources, and may need some transformation and analysis prior to the tabulation procedures described. The employment percentages for each sub-region sum to 100% as the percentage displayed is the percentage of the work force employed in the specific industry group.

Next, the inter-sub-region commodity flows must be determined from the available data. This process involves the following steps. First the GR-5 to GR-5 flow from Table 1 is distributed to each sub-region based on the percentage of households within each sub-region. This distribution determines the amount of commodity flow attracted by each sub-region. Second, the GR-5 to GR-5 flow of commodity group 1 from Table 3 is distributed to each sub-region based on the percentage of industry group1 employment in GR-5 that each sub-region is responsible for. The GR-5 to GR-5 flow of commodity group 2 from Table 4 is similarly distributed to each sub-region based on the percent employment of industry group 2. These two procedures determine the amount of commodity flow by truck produced in each sub-region. Depending on the data source used and assumptions made in the data extraction process, the sum of productions might not equal the sum of attractions within the overall geographic entity of interest. In the event an unbalanced situation exists, a balancing procedure may be used to equilibrate the sum of productions with the sum of attractions. In this simplified example balancing is unnecessary as the sum of productions (Table 3 and Table 4- the summation of the respective flows associated with commodity group 1 and commodity group 2) equal the sum of attractions (from Table 1). Table 7 presents the balanced productions and attractions for the Origin-Destination pair GR-5 to GR-5 and the associated sub-region flows.

Table 7: Balanced Productions and Attractions of Commodity Flow from GR-5 to GR-5

	Sub-region				TOTAL
	SR-1	SR-2	SR-3	SR-4	
Group 1 Productions	200	40	100	60	
Group 2 Productions	100	20	50	30	
Total Productions	300	60	150	90	600
Total Attractions	150	180	90	180	600

The balanced productions and attractions are then distributed over the origins and destinations (sub-regions) of the network according to a freight trip distribution model (gravity model).

Prior to applying the gravity model the impedance (typically distance, time or cost) and friction factor of the highway network must be determined. The friction factor function applied in this analysis specified by the *QRFM* is of the form:

$$F_{ij} = \exp(-0.03 * T_{ij}) \qquad (1)$$

where:

F_{ij} = friction factor between i and j
i = origin
j = destination
T_{ij} = travel time between i and j (impedance)

Given the highway network shown in Figure 2, an impedance matrix and friction factors corresponding to the shortest path between each Origin-Destination pair can be determined. Figure 2 shows the boundaries of each sub-region and the highway network serving the entire area. A centroid (a theoretical point at the geographic center of each area entity) is assigned to each sub-region, serving as both the origin and destination of all trips (commodity flow). Each centroid is connected to the existing highway network with a centroid connector, a link that gives access to and from the points of origin and destination. In Figure 2 the solid black lines are sub region boundaries and the broken lines symbolize links in the highway network. The gray circles are sub-region centroids, which connect to highway links through the centroid connectors.

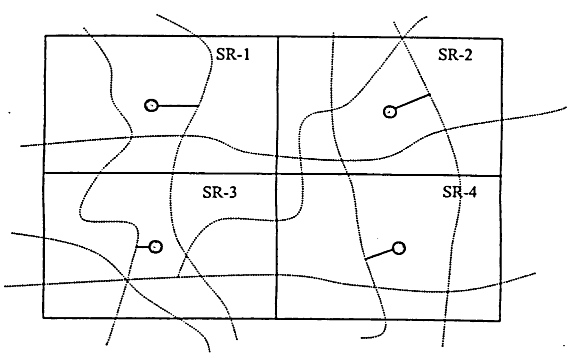


Figure 3: Example Sub-Region Highway Network

A shortest path algorithm is applied to determine the travel impedance (in this case time in minutes) between all zones of interest (SR-1, SR-2, SR-3, SR-4). The results of the shortest path algorithm are shown in Table 8.

Table 8: Impedance Matrix (travel time in minutes)

	Destinations			
Origins	SR-1	SR-2	SR-3	SR-4
SR-1	0	33.33	40	66.67
SR-2	33.33	0	73.33	26.67
SR-3	40	73.33	0	33.33
SR-4	66.67	26.67	33.33	0

Based on the calculated impedance, friction factors can be determined according to equation 1. The calculated friction factors are shown in Table 9.

Table 9: Friction Factor Matrix

	Destinations			
Origins	SR-1	SR-2	SR-3	SR-4
SR-1	1	0.368	0.301	0.135
SR-2	0.368	1	0.111	0.449
SR-3	0.301	0.111	1	0.368
SR-4	0.135	0.449	0.368	1

A gravity model considers the previously determined trip origins and destinations for each zone and the friction factor for travel between zones to determine the trip interchange flows. The gravity model is of the form:

$$V_{ij} = O_i * \frac{D_j F_{ij}}{\sum_j D_j F_{ij}} \qquad \forall i \qquad (2)$$

where:

V_{ij} = trip interchanges between origin i and destination j
O_i = number of trips originating at i
D_j = number of trips destined at j

Application of the gravity model based on the calculated trip origins, destinations and friction factors determines the commodity flow between origins and destinations of the network. A summary of the commodity flows at the sub-region level, determined by gravity model application, is shown in Table 10.

Table 10: Commodity Flow at the Sub-Region Level

	Destination				
Origin	SR-1	SR-2	SR-3	SR-4	Sum
SR-1	168	74	30	27	300
SR-2	10	33	2	15	60
SR-3	31	14	61	45	150
SR-4	6	23	9	52	90
Sum	215	144	102	139	600

The integration of Table 2, Table 5, Table 6 and Table 10 results in the Origin-Destination Trip Matrix, shown in Table 11.

Table 11: Example Origin-Destination Trip Table

Origin	Destination								Sum
	GR-1	GR-2	GR-3	GR-4	SR-1	SR-2	SR-3	SR-4	
GR-1	0	0	0	0	250	300	150	300	1000
GR-2	0	0	0	0	125	150	75	150	500
GR-3	0	0	0	0	188	225	112	225	750
GR-4	0	0	0	0	50	60	30	60	200
SR-1	688	1050	400	625	168	74	30	27	3062
SR-2	212	230	180	225	10	33	2	15	907
SR-3	587	590	525	638	31	14	61	45	2491
SR-4	263	330	195	262	6	23	9	52	1140
Sum	1750	2200	1300	1750	828	879	469	874	10050

Table 11 indicates that 2450 (highlighted cells on upper right of Table 11) tons of commodity travel into GR-5 from surrounding regions. Specifically (of the 2450 tons total) 1000 tons are from GR-1, 500 tons are from GR-2, 750 tons are from GR-3 and 200 tons are from GR-4. Further, 7000 tons of commodity travel from GR-5 to surrounding regions. Of this total, 1750 tons are destined to GR-1, 2200 tons are destined to GR-2, 1300 tons are destined to GR-3 and 1750 tons are destined to GR-4. Also, the matrix indicates the tons of commodity moving into and out of any geographic region or sub-region of interest.

METHODOLOGICAL FRAMEWORK

The procedure developed and used in the previous example can be summarized in four major tasks. Following is an outline of these tasks. A detailed discussion is presented in Section 4, through an application of the proposed method to the estimation of commodity flows into and out of Pennsylvania counties.

Task 1

- Review and Acquisition of data on freight flows in the U.S.
- Determination of appropriate data sources for this study

Task 2

A.

- Freight Flow Data Extraction
- QRFM Classifications
    - Commodity Type

B.

- Population Characteristics Data Extraction
- U.S. Department of Transportation Bureau of Transportation Statistics
    - Distribution by County Employment Percentage
    - Distribution by County Household Percentage

C.

- Geographical Data Extraction
- National Transportation Atlas Databases 1996
    - State Highway Network
    - County Map

Task 3

- Commodity Distribution
    - State to County
    - County to State
        - Commodity Group 1
        - Commodity Group 2
    - County to County

Task 4

- Data Recombination
    - Origin-Destination Trip Matrix Development

A graphical representation of the proposed method with reference to the above outlined tasks is shown in Figure 3.

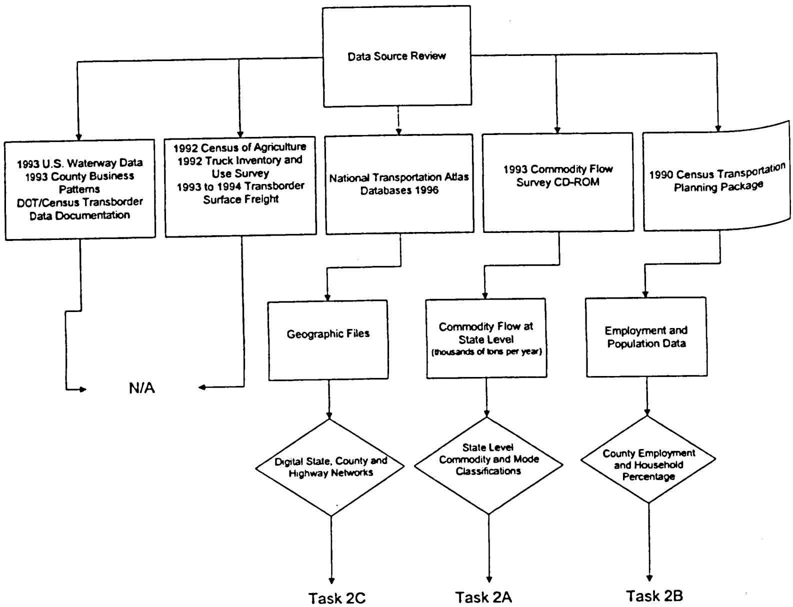
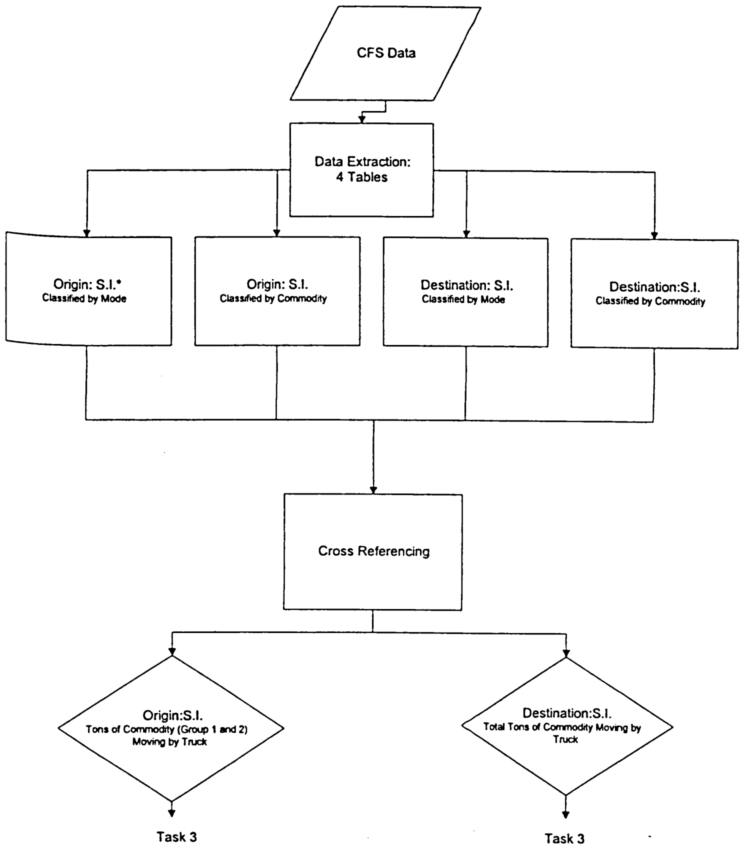


Figure 3: Methodological Framework - Task 1



* S.I. : State of Interest

Figure 3 (continued): Methodological Framework - Task 2A

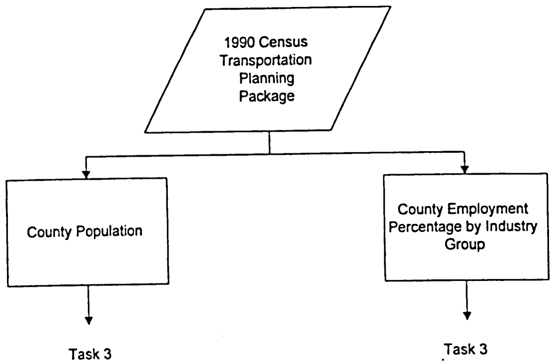


Figure 3: (continued): Methodological Framework- Task 2B

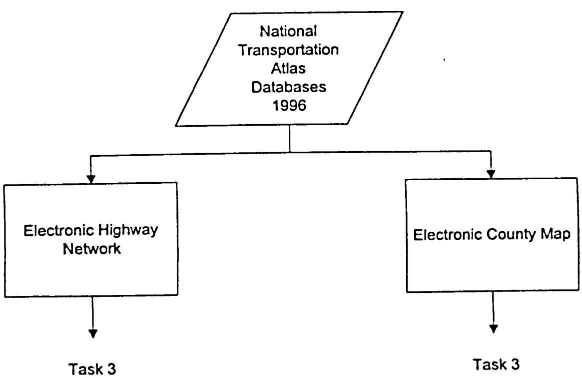


Figure 3 (continued): Methodological Framework - Task 2C

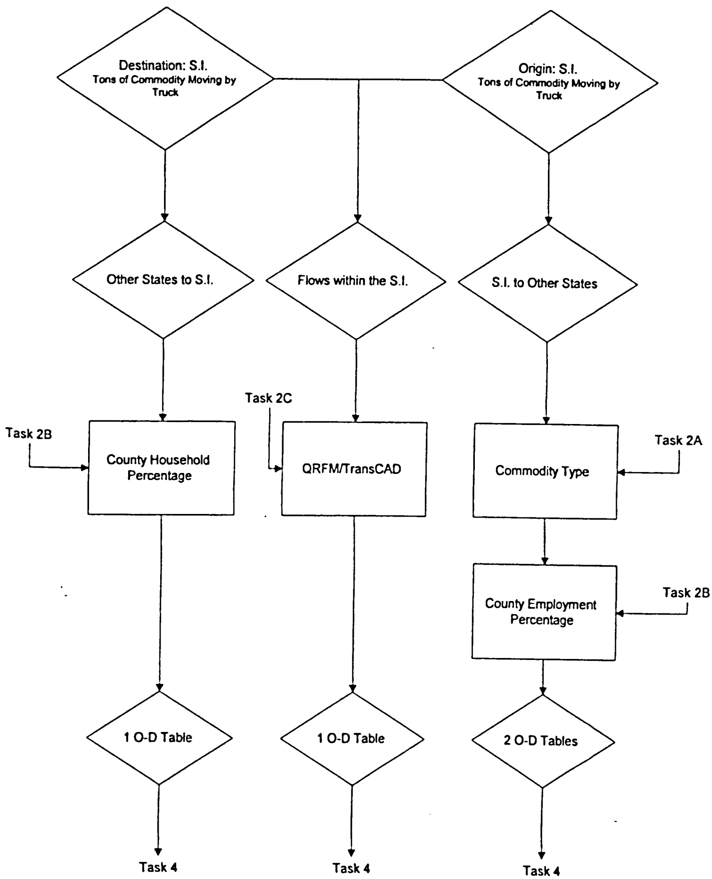


Figure 3 (continued): Methodological Framework - Task 3

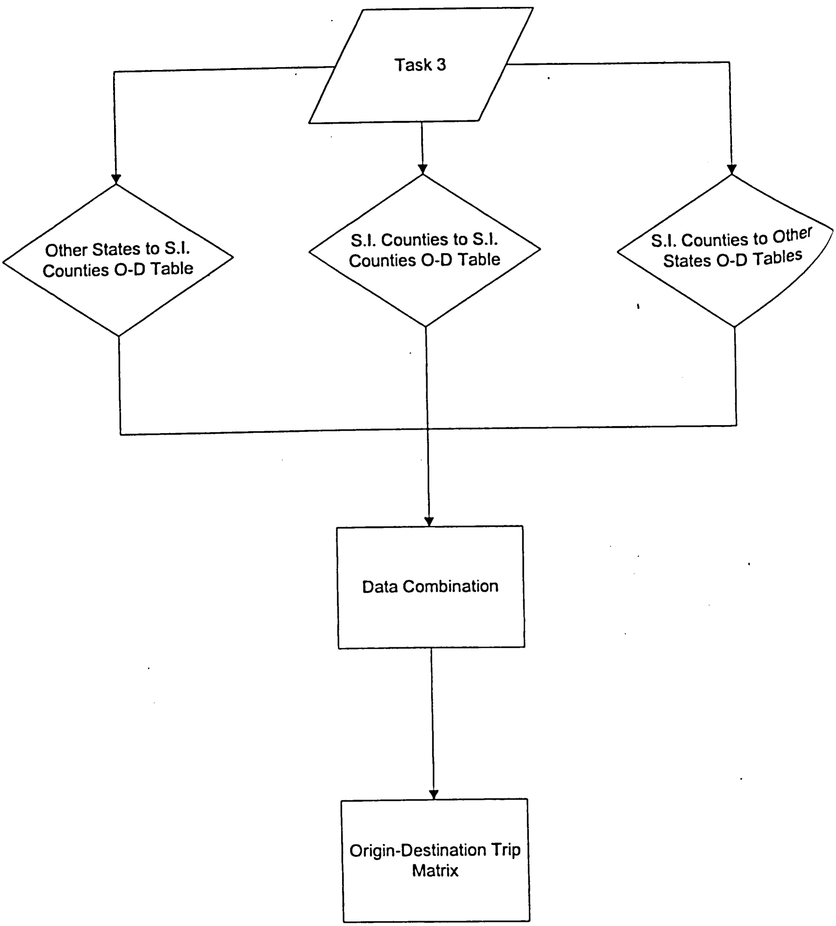


Figure 3 (continued): Methodological Framework - Task 4

CASE STUDY: DEVELOPMENT OF A COMMODITY FLOW ORIGIN-DESTINATION MATRIX FOR PENNSYLVANIA

Task 1: Data Source Review and Selection

Three types of data are necessary to complete the process outlined in section 3; commodity flow data, geographic data, and census data. Numerous data sources exist that describe characteristics of commodity flow. This project uses data sources detailing commodity flow by truck at the state level. Following is a short description of data sources considered for this application. The 1992 *Census of Agriculture* describes agricultural production on multiple geographic levels- national, state and county. The *Truck Inventory and Use Survey (TIUS)* (1995) describes commodity flow by truck, providing detailed physical and operational descriptions of trucks- model year, body type, empty weight, truck type, axle arrangement, length, engine size, products carried, annual and lifetime miles, miles per gallon etc. This data source classifies vehicles by state of registration; the actual origin and destination of the commodity shipped is not known. The *Surface Transborder Freight* (1993) details imports shipped by truck from Mexico and Canada. No information exists that specifically describes Pennsylvania transit data. The *U.S. Waterway Data* (1994) describes imports received by maritime ports, classifying the import by commodity code and tonnage. The *County Business Patterns* (1994) provides information on establishments and employment by SIC (Standard Industrial Classification) concerning U.S. businesses. The *1993 Commodity Flow Survey (CFS)* details commodity flow by mode and type between all states. This data source was determined to be the most relevant and directly applicable to this study. A summary of Pennsylvania data as well as a discussion of features and limitations of *CFS* is available in the *Freight Transportation in Pennsylvania- Selected Data from Federal Sources* handbook (1996), produced by the U.S. department of Transportation.

Geographic data is available in many formats and from multiple sources. However, the majority of this information derives from the *National Transportation Atlas Databases* (1996) produced by the Bureau of Transportation Statistics (BTS). This CD-ROM contains point, line and area data that describes transportation networks and terminals, as well as overall geographic features. Connected databases numerically describe all attributes and systems of interest. Census data available in the *1990 Census Transportation Planning Package*, produced by the Bureau of Transportation Statistics is used to obtain county level employment and population data. Other sources, such as *TIGER/Line 1995* are available but redundant.

Task 2: Data Extraction and cross-referencing

A: *CFS* Data Extraction and *QRFM* Designations/Classifications

The purpose of this section of the analysis is to produce tables that describe commodity flow between all states by mode and commodity type. A description of the contents of tables developed and used will be given, however, due to their size, the actual tables will not be included in the document.

CFS groups commodities into two digit Standard Transportation Commodity Code (STCC) categories. Information on commodity flow (by mode and commodity grouping) between Pennsylvania and all other external stations (U.S. States) is extracted from CFS. This information is classified in four large tables as follows:

1. Origin in Pennsylvania (Classified by Mode of Transport)

The information in this table includes all of the commodity flows between Pennsylvania and the other states. Each O-D pairing (ex. Pennsylvania to Wyoming) divides the tons of commodity by the mode of transport that is used.

2. Origin is Pennsylvania (Classified by Commodity)

The data includes all of the Commodity flows between Pennsylvania and the other states. Each O-D pairing divides the total tons of commodity into two-digit STCC groups.

3. Destination is Pennsylvania (Classified by Mode of Transport)

This table includes the commodity flows from all of the states to Pennsylvania. Each O-D grouping is divided based on the mode of transport that is used.

4. Destination is Pennsylvania (Classified by Commodity)

This data includes the commodity flows from all of the states to Pennsylvania. For each O-D pair, the total tons of commodity are divided into two- digit STCC groups.

First, the percentage of total commodity that travels by truck must be determined for both Pennsylvania as an origin and Pennsylvania as a destination. The following single modes are available to choose from:

CODE	POPCODE	DESC
1	0	ALL MODES
10		SINGLE
11	1	Parcel, U.S. Postal Service, or courier
12	2	Private truck
13	3	For-hire truck
14	4	Air

15	5	Rail
16	6	Inland water
17	7	Great Lakes
18	9	Deep sea water
19	10	Pipeline

Private truck and for-hire truck (POPCODE 02 and 03) are chosen, as they are the two modes that apply to this study. The total weight of all commodities transported by all modes originating in Pennsylvania is determined. Next the weights moving by private or for-hire truck are summed. This sum is divided by the total weight transported by all modes to find the percentage of all commodities originating in Pennsylvania travelling by truck. A similar procedure is followed for commodities destined for Pennsylvania and the percentage of all commodities destined for Pennsylvania travelling by truck is calculated. The resulting transit mode percentages are multiplied by the commodity flows that move into and out of Pennsylvania to determine the flow of each commodity moving by truck into and out of Pennsylvania.

These flows are further classified into two commodity groups. Each commodity group is representative of an industry group described in the *QRFM*. Group 1 includes Agriculture, Mining and Construction industries (SIC 1-19) and contains commodity representative of these industries. Group 2 includes Manufacturing, Transportation/ Communication/Utilities and Wholesale Trade (SIC 20-51) and contains commodities representative of these industries. The final outcome of this part of the process is a table describing the flow of commodities moving by truck into Pennsylvania (from all other U.S. States) and two tables describing the flow of commodity group 1 and commodity group 2 (separately) moving by truck from Pennsylvania to all U.S. States.

B: Population Characteristics Data Extraction

Population and employment data for the state of Pennsylvania is extracted from the *1990 Census Transportation Planning Package (CTPP)* available from the Bureau of Transportation Statistics. The number of households per county in Pennsylvania is extracted from the data set and uploaded to a spreadsheet program. The percentage of households per Pennsylvania County can then be determined as shown in Figure 4.

Next, the number of workers per industry group per county is estimated. The *CTPP* data contains numerous fields describing different professions. These are classified under the two groups presented in Task 2A as follows:

Commodity Group 1

B03_0102: Agriculture, Forestry and Fisheries
B03_0103: Mining
B03_0104: Construction

Commodity Group 2

B03_0105: Manufacturing, non-durable goods
B03_0106: Manufacturing, durable goods
B03_0107: Transportation
B03_0108: Communications and Public Utilities
B03_0109: Wholesale Trade

Figure 5A shows the percentage of industry group 1 and Figure 5B shows the percentage of industry group 2 employment in each Pennsylvania County.

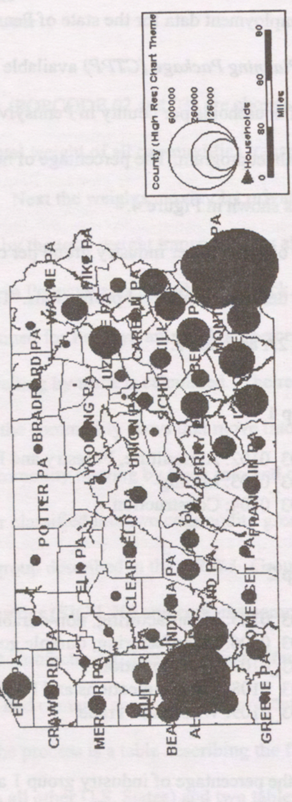


Figure 4: Household Percentage in Pennsylvania Counties

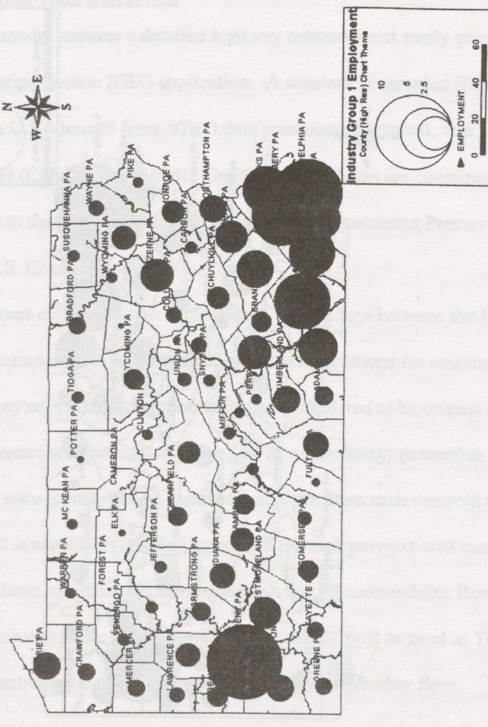


Figure 5A: Percentage of Industry Group 1 Employment in Pennsylvania Counties

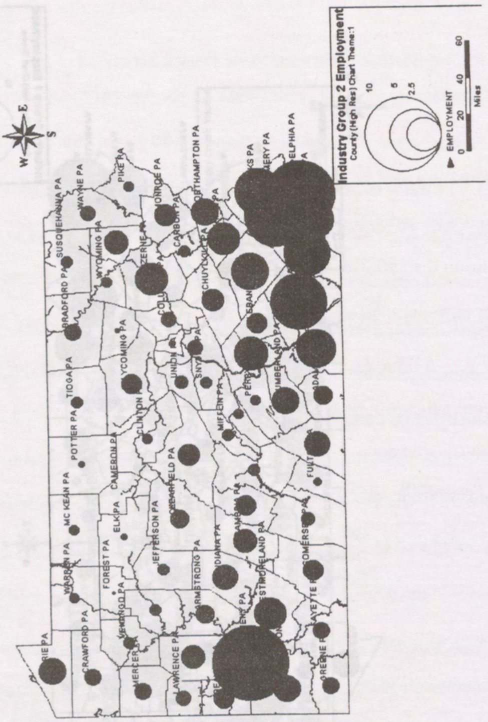


Figure 5B: Percentage of Industry Group 2 Employment in Pennsylvania Counties

C: Geographic Data Extraction

The gravity model requires a detailed highway network most easily produced via a Geographic Information System (GIS) application. A standard geographic file of all interstate highways across the U.S., derived from *NTAD* data previously discussed, was opened in TransCAD (Caliper Corp. 1996). Geographic attributes are contained in database format and attached to the geographic file. In addition, a file containing Pennsylvania Counties is selected from the U.S. Counties data set.

Analysis techniques outlined in task three require an interface between the highway network and counties. The counties must act as both origins and destinations for commodity that will flow over the highway network. Production zones are considered to be origins of commodity flow and attraction zones are destinations. The *QRFM* methodology prescribes the assignment of centroids to each zone (county) and a centroid connector from each centroid to the highway network. TransCAD is capable of creating a centroid for each polygon area corresponding to a county. This simplification introduces the assumption that all commodities flowing to or from a county come from this one point. The geographic files created will be used in Task 3 to balance productions and attractions and distribute county to county commodity flow.

Task 3: Data Disaggregation and Commodity Distribution

Three different types of commodity flow are to be analyzed, each requiring a different distribution methodology. Previous sections of this report have manipulated commodity data such that flows by truck are known from all states to Pennsylvania and from Pennsylvania to all states. Also, the percentage of households per Pennsylvania County and employment percentage per county per industry group are known, and the Pennsylvania highway network has been created. Commodity flow from all states to Pennsylvania (Pennsylvania is the destination) are now analyzed. The commodity weight transported by truck (in thousands of tons per year) must be distributed within Pennsylvania. Commodity grouping is not considered as only an overall tonnage is desired. This distribution is performed with the previously calculated household percentage per Pennsylvania County. The commodity flows moving by truck from each state to each Pennsylvania County are estimated.

The total of each commodity group travelling by truck from Pennsylvania to each other state is known. These flows can be distributed back to Pennsylvania Counties based on the employment percentage (calculated in Task 2) per industry group in the county. Performing these calculations results in two new data tables. The first table describes the flow of commodities in group 1 and the second describes flow of commodities in group 2 originating in each Pennsylvania County and destined to each other state.

The Pennsylvania to Pennsylvania Origin-Destination pairing will be used to calculate county to county flows. The purpose of this phase of the analysis is to produce a trip table that describes the commodity flow between counties. There is no explicit data that details the total tonnage transported between counties. Consequently statistical models that distribute flow based on productions and attractions at the state level are employed.

Significant portions of previous calculations and data can be re-used for this part of the analysis. Two new data tables are developed. The first one contains information on commodities originating in Pennsylvania and have Pennsylvania as a destination. The second contains information on commodities destined for Pennsylvania and have Pennsylvania as an origin. (The tables are expected to present identical information). Next the data contained in each of these tables must be distributed to the Pennsylvania Counties and combined together. For the commodities destined to Pennsylvania the total commodity weight multiplied by the percentage of commodity that travels by truck is distributed based on population. The commodities originating in Pennsylvania must first be divided into the two commodity groups, then multiplied by the corresponding percentage of freight travelling by truck and then distributed based on employment percentage.

In addition to the number of trip origins and destinations a friction factor of travel between zones (counties) must be estimated. A shortest path analysis is performed in TransCAD to determine the minimum time between all county centroids on the highway network. As a result of the shortest path analysis, an impedance matrix, according to equation (1), and a friction factor matrix are calculated. TransCAD is again applied to perform trip distribution according to a gravity model (equation 2). The resulting county to county Origin-Destination matrix of commodity flow by truck in tonnage per year is then developed.

Task 4: Data Recombination: Origin-Destination Trip Matrix Development

The estimated flows (Pennsylvania Counties to U.S. States, U.S. States to Pennsylvania Counties and Pennsylvania Counties to Pennsylvania Counties) can be combined to form the final trip table. The trip table is a large origin-destination matrix with all counties and all states as both origins and destinations. Three quarters of this table are filled, as state to state flow (available through *CFS*) is not considered in this study.

The trip origins and destinations (in tons of commodity per year moving by truck) for each Pennsylvania County are shown in Figure 6.

CONCLUSIONS

A method was developed and used to estimate the commodity flows moving by truck into and out of Pennsylvania Counties. The resulting Origin-Destination trip matrix summarizes all types of commodity flow (U.S. States to Pennsylvania Counties, Pennsylvania Counties to U.S. States, and Pennsylvania County to Pennsylvania County).

Future research could involve analysis of commodity flow at a more disaggregate level. For example, in this application it was assumed that commodities are attracted by the destination zones proportionally to the household density of each zone, meaning that commodities will be consumed equally by households. Future research may consider different distribution methods, specific to each particular commodity. In addition, appropriate traffic assignment techniques can be selected to assign the commodity trip interchanges over the truck route network for the state of Pennsylvania. Subsequent to traffic assignment, it is possible to determine both under and over utilized links on the Pennsylvania highway network. This determination can then be used as a basis for setting a schedule for priority road maintenance as well as education to truck drivers about less crowded paths between popular origins and destinations. Also, by comparing the Trip Table to actual data (as it becomes available) it is possible to re-calibrate many of the models and statistical assumptions used in this report.

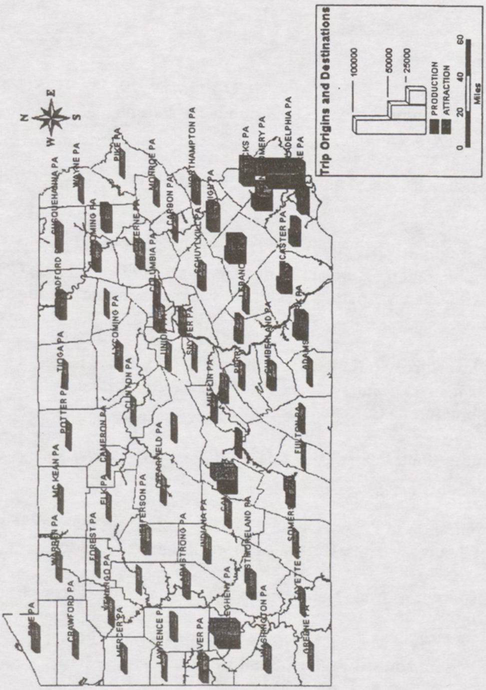


Figure 6: Trip Origins and Destinations (in tons of commodity per year)

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