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Assembling and Processing Freight Shipment Data: Developing a GIS-Based Origin-Destination Matrix for Southern California Freight Flows

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16. Abstract

Freight movements within large metropolitan areas are much less studied and analyzed than personal travel. This casts doubt on the results of much conventional travel demand modeling and planning. With so much traffic overlooked, how plausible are the results?

The goal of this research is to propose and execute a systematic non-survey based method to overcome this common omission and develop an origin-destination (O-D) matrix of freight flows. Our approach is based on secondary data sources, most of which are widely available.

We also plan to load the estimated freight flows and concurrent passenger volumes onto the regional highway network of a large metropolitan region, the greater Los Angeles area of Southern California. Our approach illustrates a low-cost way in which metropolitan planning agencies can meet the problem of missing freight flow information.

After collecting, processing and manipulating freight data for the Southern California region from most of the available and relevant sources, we analyze the various freight movements in and out of the region, through the region, as well as within it. Most of the data are allocated to more than 1,500 Traffic Analysis Zones (TAZs). By integrating economic analysis, transportation modeling and GIS technologies, a GIS-based origin-destination matrix was built for Southern California freight flows. The results of the freight O-D matrix calculations are shown to be reliable through various checks with control totals.

To load the freight flows onto the regional highway network, a three-step feedback transportation model was developed. It includes trip generation, trip distribution, and traffic assignment. Most of the trip generation work was done during the construction of the GIS-based origin-destination matrix.

A doubly-constrained gravity model was used to co-distribute and calibrate personal trips and freight trips in the trip distribution step. A version of User-Optimal-Strict On Network Assignment (UO-S-NA) will be utilized to assign all of the vehicle trips to the regional highway network.

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Abstract

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The goal of this research is to propose and execute a systematic non-survey based method to overcome this common omission and develop an origin-destination (O-D) matrix of freight flows. Our approach is based on secondary data sources, most of which are widely available.

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1. Introduction

The analysis of intraregional freight movement is a complex and largely unexplored issue due to the variety of data sources, many of them corresponding to various geographical and sectoral definitions. A related problem stems from the lack of standard methodologies, software and approaches. Metropolitan planning agencies routinely conduct origin-destination surveys as part of their travel demand modeling and forecasting activities. Yet, most of these focus on passenger travel; loading large-scale highway networks with just passenger data can be the basis of substantial error. Trucking is the dominant mode of freight movement in the U.S., accounting for 89 percent the value of all freight shipments in 1997 (US DOT, 1998b) and with VMT growth substantially exceeding GDP growth in the period 1980-97.

The purpose of this prototypical study is to suggest a systematic non-survey based approach to this problem. We have found that the available data can be processed so that a reasonable accurate origin-destination matrix of freight flows can be estimated. As usual, various assumptions have had to be made but these were reasonable and often confirmed via double-checking of the results with alternate data sources. On-going work involves loading these data onto the regional highway network.

We focus on the five-county metropolitan region surrounding and including Los Angeles county, hereafter referred to as the SCAG (Southern California Association of Governments) region. For that area, we have identified and collected most of the available and relevant freight data. We analyzed freight movements in and out of the region, through the region, as well as within it. We have also integrated economic analysis, transportation modeling and GIS technologies.

With the growing recognition of the importance of freight transportation to regional economies and their infrastructure, several studies have been conducted by local agencies that are useful to our efforts. For example, SCAG finished an interregional goods movement study in 1996 and the California Department of Transportation (CALTRANS) released an Intermodal Transportation Management System (ITMS) in 1996. Their work is an essential basis for a freight movement study of the SCAG region.

Based on these and other data sources and various methodologies, this investigation focuses on freight movement, with the aim of loading freight flows onto the available regional highway network. The key task is to implement an economic analysis and GIS technologies along with traditional transportation modeling.

The study area includes Los Angeles, Orange, Riverside, San Bernardino and Ventura counties (Figure 1). The area covers more than 35,000 square miles. The 2000 population of the five-county area was nearly 16.4 million. In 1990, the urbanized portions extended to 1,966 square miles; population density in the urbanized area was about 5,801 people per square mile, highest in the U.S. The urbanized area is described in terms of SCAG's 1527 disaggregate traffic analysis zones (TAZs). The regional highway network includes 22,244 links.

Table 1.1 provides additional recent aggregate data describing the study area. Table 1.2 summaries the area's international trade by major mode. The total households in the area were 5.4 million in 1998 (US Bureau of Census). The nonfarm employment in the SCAG region was over 5.8 million in 1997. Personal income in the area was $329.6 billion and per capita personal income was $21,542 in 1994. 21.6 percent of income was goods-related and 78 percent of income was service related. The employment distribution across industry sectors were: 34.3 percent in services, 16.4 percent in manufacturing, 13.3 percent in government, 9.6 percent in retail, and 7.3 percent in FIRE. International exports from the five-county area have been reported to be $35.7 billion in 1996 (Exporter Location Series, US Bureau of the Census); our analysis suggests, however, that this may have been a significant underestimate.

Table 1.1 SOCIO-ECONOMIC PROFILE, SCAG FIVE-COUNTY AREA

COUNTY	Population (persons)	Households (1,000)	Employment (paid employees)	Total Personal Income ($1,000)	Per Capita Income ($)	Land Area (square miles)
Year	2000	1998	1997	1994	1994	1990
Los Angeles	9,519,338	3,136.6	3,693,537	197,289,098	21,562	4,060
Orange	2,846,289	941.0	1,212,689	64,892,666	25,516	790
Riverside	1,545,387	1,037.9*	319,904	25,086,809	18,543	7,208
San Bernardino	1,709,434	*	406,859	26,477,943	17,043	20,062
Ventura	753,197	239.9	211,591	15,899,444	22,625	1,846
Five-County	16,373,645	5,355.4	5,844,580	329,645,960	21,542	33,966

Source: U.S. Census Bureau's state and county quick facts (http://quickfacts.census.gov/qfd/)

Note: *Data for Riverside-San Bernardino PMSA

Values of employment (private nonfarm employment) and land area from People QuickFacts for each individual county. Values of population come from USA Counties General Profile for each individual county. Values of total personal income and per capita personal income from Local Area Personal Income data of Bureau of Economic Analysis (BEA).

The international, interregional and intraregional freight movements in and out of the five counties pass through two major seaports, Long Beach and Los Angeles; five major airports, LAX, Ontario, Long Beach, Burbank, and John Wayne; as well as three rail yards, and twelve highway entry points (we have omitted pipeline flows from this study).

Throughout this study, freight trip generation was calculated as a function of local (Traffic Analysis Zone; TAZ) employment *plus* any shipments entering or leaving the region via that TAZ. The addresses of seaports, airports and rail yards are known. Trips generated at the twelve highway entry-point Traffic Analysis Zones (TAZs) were included in trips generated to or from the appropriate boundary TAZs.

We summarize the international trade by major mode to and from the SCAG region in Table 1.2. One reason for the difference between Exporter Location data and the summarized values is that export totals for some metro areas in the census report are somewhat understated (Technical Notes of Metro Area Exporter Location Data, http://www.ita.doc.gov/td/industry/ otea/metro/technote.html). Another reason is that intermodal freight moves from one mode to another so that the same commodities may appear in multiple mode categories in our table.

The rest of this report is divided into six parts. Part 2 describes the various data sources that were utilized. Part 3 processes these data to make them amenable to our analysis. Part 4 focuses on data integration. Part 5 discusses network analysis. This is followed by Part 6, which discusses conclusions, reflections and suggestions for further research.

Table 1.2 INTERNATIONAL TRADE BY MAJOR MODE, SCAG REGION, 1996

(Millions of dollars)

	Air	Sea	Land	Total
Imports	55,385	43,739	6,780	105,904
Exports	55,385	43,754	4,182	103,321

Source: Author calculation based on Table 3.2, Table 3.7, Table 3.12 and Table 3.15.

Note: International trade by air is calculated from Table 3.7. International trade by sea is calculated from Table 3.2. Total trade by land is the sum of trade by rail (Table 3.12) and trade by highway (Table 3.15). The ratio of international imports by land is 4.48% of the total imports and the ratio of international exports by land is 3.52% of total exports. These ratios are calculated from Interregional Goods Movement Study (SCAG 1996). Another source indicates that international trade for the Los Angeles Customs District is $207 billion in 1995 (http://www.ucop.edu/cprc/eriebrf.html), which is similar to our result.

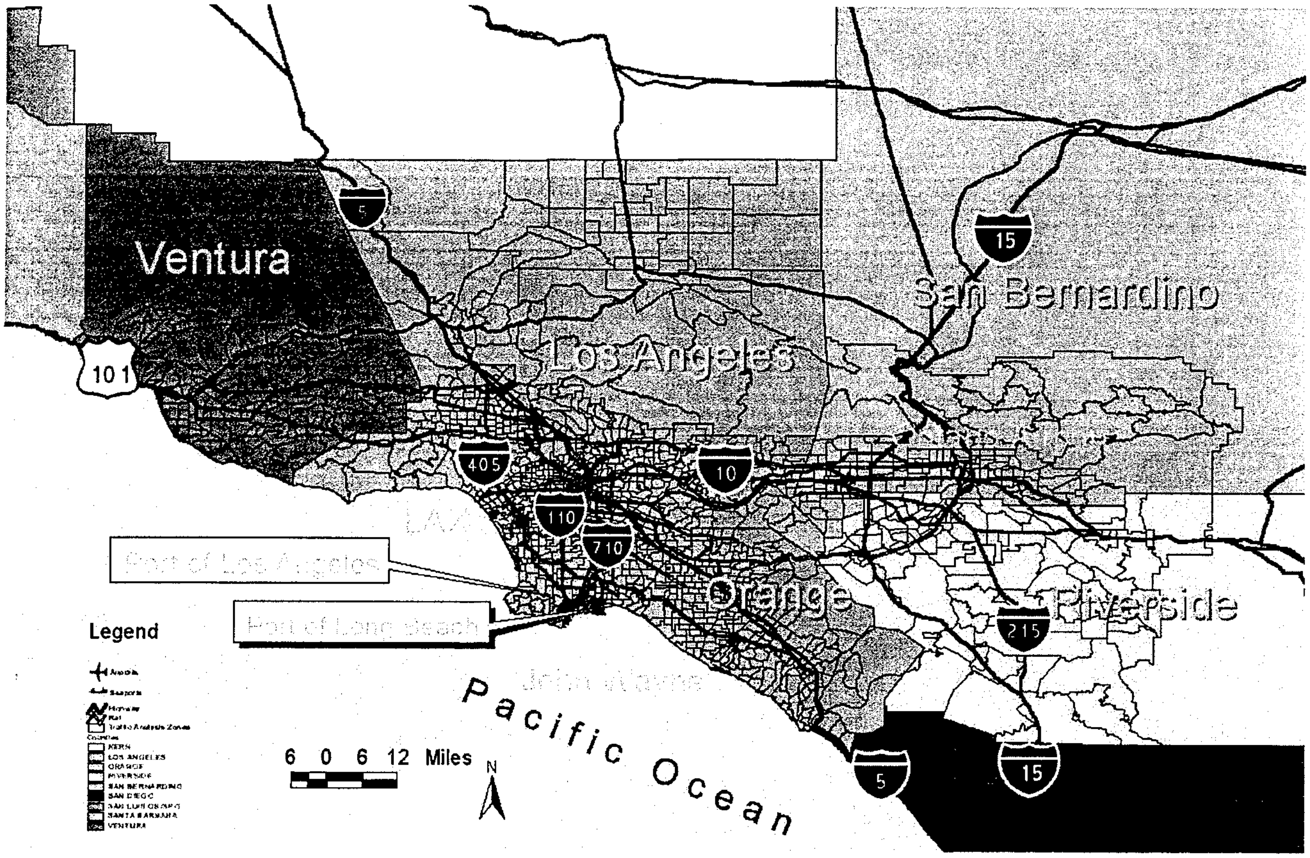

Figure 1.1 Transportation Networks, SCAG Region

2. Freight Data Sources

This study rests on data on economic activities, freight imports and exports at local seaports and airports, by highway and by rail. The available sources for employment data include census data from the 1990 Census Transportation Planning Package (CTPP), as well as more recent surveys by SCAG. The data for imports and exports of goods at local seaports were obtained from the Waterborne Commerce Statistics Center of the U.S. Army Corps of Engineers as well as SCAG freight studies. SCAG has also conducted various aviation studies, which provide data on air cargo. Statistics found at various airport websites also include information on imports and exports of air cargo.

An important source for data on freight movement in and out of the SCAG region by rail or highway is from the California Department of Transportation 's (CalTrans') Intermodal Transportation Management System (ITMS). Another useful source is SCAG's Inter-regional Goods Movement Study. Detailed sectoral data on regional economic activities within the SCAG region are based on a 515-sector input-output transactions table for 1990, which was generated from Regional Science Research Institute's PC-IO package.

2.1. Employment Data

(1) Census Transportation Planning Package (CTPP), 1990

CTPP includes information about jobs by economic sector and by place of work. For each census tract, CTPP categorizes employment into the following eighteen sectors:

- Agriculture, forestry, and fisheries
- Mining
- Construction
- Manufacturing, nondurable goods
- Manufacturing, durable goods
- Transportation
- Communications and other public utilities
- Wholesale trade
- Retail trade
- Finance, insurance, and real estate
- Business and repair services
- Personal services
- Entertainment and recreation services
- Health services
- Educational services
- Other professional and related services
- Public administration
- Armed Forces (Not used here)

Putting aside armed forces jobs, the first 17 sector identifications are used throughout in our employment data base.

(2) SCAG Employment Data, 1990 and 1994

For comparison, SCAG provides employment data for 1990 and 1994. SCAG categorizes the employment data into 3- digit or 4-digit standard industry code (SIC code) for each tract. These employment data were used for comparison purposes with the CTPP results.

2.2. Seaports

The Waterborne Commerce Statistics Center of the U.S. Army Corps of Engineers archives vessel trip and cargo data for all major seaports in the U.S. The Center's Waterborne Commerce of the United States (WCUS) data includes statistics on foreign and domestic waterborne commerce at U.S. seaports. This commerce is reported by STCC (Standard Transportation Commodity Classification) categories for inbound and outbound foreign and domestic goods. These had to be aggregated to match the seventeen economic sectors listed above. We used 1996 WCUS data for shipments in and out of Long Beach and Los Angeles harbors.

WCUS data includes no information about the origin of export goods or the destination of import goods. The SCAG Inter-regional Goods Movement Study (1996) provided geographic ratios of goods originated in or destined to the SCAG region. The SCAG Heavy Duty Truck Model and SCAG VMT Estimates for 1999 provided more detailed origin and destination information for seaport-generated daily truck trips. We used these as a complement to the WCUS data.

2.3. Airports

Statistics available from various airport web pages contain summary statistics on air cargo movements in and out of SCAG region. Only the LAX and Ontario airports report cargo data. Comparing the LAX and Ontario air cargo data available on their web pages with the percentage from the SCAG report, Air Cargo in SCAG Region (SCAG, 1992), we found a good match. Air cargo data for the other airports were derived from their regional share as denoted in the SCAG report. RAND also publishes statistics on airports throughout California, including the major airports of the SCAG region. We utilized RAND data for comparison purposes.

2.4. Rail and Highways

The Intermodal Transportation Management System (ITMS) provided freight movement data in and out of the SCAG region by rail and by highway. The ITMS data also categorize goods by STCC sectors. But, as with the WCUS seaport data, ITMS data for rail and highway do not include information on the origin of outbound goods or the destination of inbound goods. These were, however, available from SCAG Inter-regional Goods Movement Study for 1996 although there was not any sectoral detail.

2.5. Economic Activities

A 515-sector interindustry transactions table for 1990 was derived from the RSRI's PC-IO package. These were aggregated to the 17 sectors listed on the previous page. The PC-IO data are available in terms of the dollar value of output as well as in terms of employment; they were, therefore, used to calculate output-per-job for each of the sectors.

3. Data Processing

3.1. Employment Data

(1) Census Data for Transportation Planning Package (CTPP), 1990

The number of employees in each Traffic Analysis Zone/Census Tract was calculated from CTPP Part 2 for Los Angeles MPO (Metropolitan Planning Organization). A SAS program (Attachment A) was developed to extract the employment data from the CTPP package. Then, the numbers of employees in each TAZ were tabulated by the seventeen sectors.

Because some CTPP TAZ codes overlap (same code appears in several records) and the codes are not consistent with the 1527 TAZs defined by SCAG, applying the *ArcView GIS package*, we solved the problem via the following steps:

- Use the merge function in ArcView GIS to merge the overlapping CTPP TAZ codes; 2421 unique TAZs are generated (Figure 2).
- Split the 1527 SCAG TAZ and the 2421 CTPP TAZ by their overlapping boundaries; 4954 smaller pieces represent the matching areas of the two systems. The area ratios of the smaller pieces are calculated for both SCAG TAZs and CTPP TAZs.
- Use the value of the area ratio to desegregate the CTPP employment data to 4954 smaller matching pieces (Figure 3).
- Aggregate the 4954 smaller matching pieces with the CTPP employment data to 1527 SCAG TAZs (Figure 4).

Using this procedure, we derived employment data by 17 sectors for each of the 1527 SCAG TAZs.

(2) SCAG Employment Data, 1990 and 1994

Since SCAG employment data are classified by SIC code, a SAS program (Attachment B) was developed to aggregate them to 17 sectors. The initial SCAG employment data are allocated to 2594 TAZs. The first task was to get rid of the places not in the study area; the number of remaining TAZs is 2421. These areas are the same as those of the initial CTPP employment data (Figures 5 and 6).

The same procedure as above was followed to derive employment data for the 1527 TAZs. For comparison purposes, the SCAG employment data for 2421 TAZs are appropriate for finding the difference with the initial CTPP data at the same 2421 TAZs.

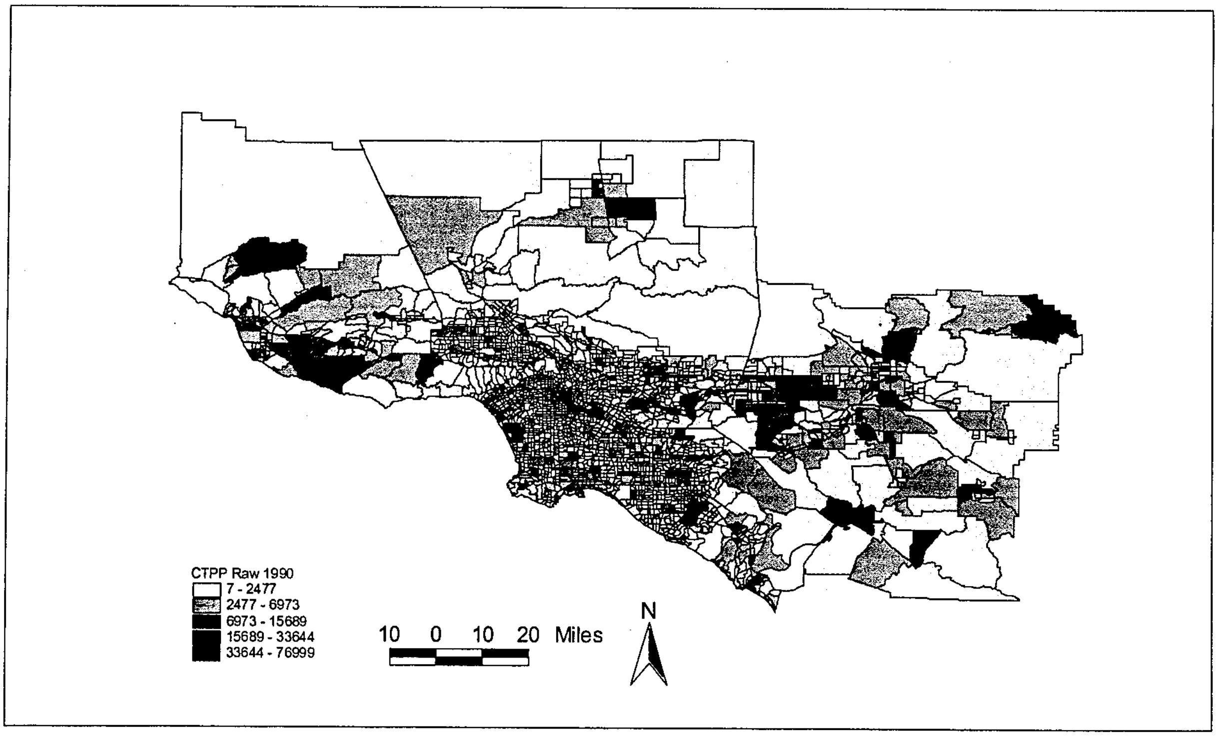

Figure 3.1 CTPP employment data in 1990 (2421 TAZs).

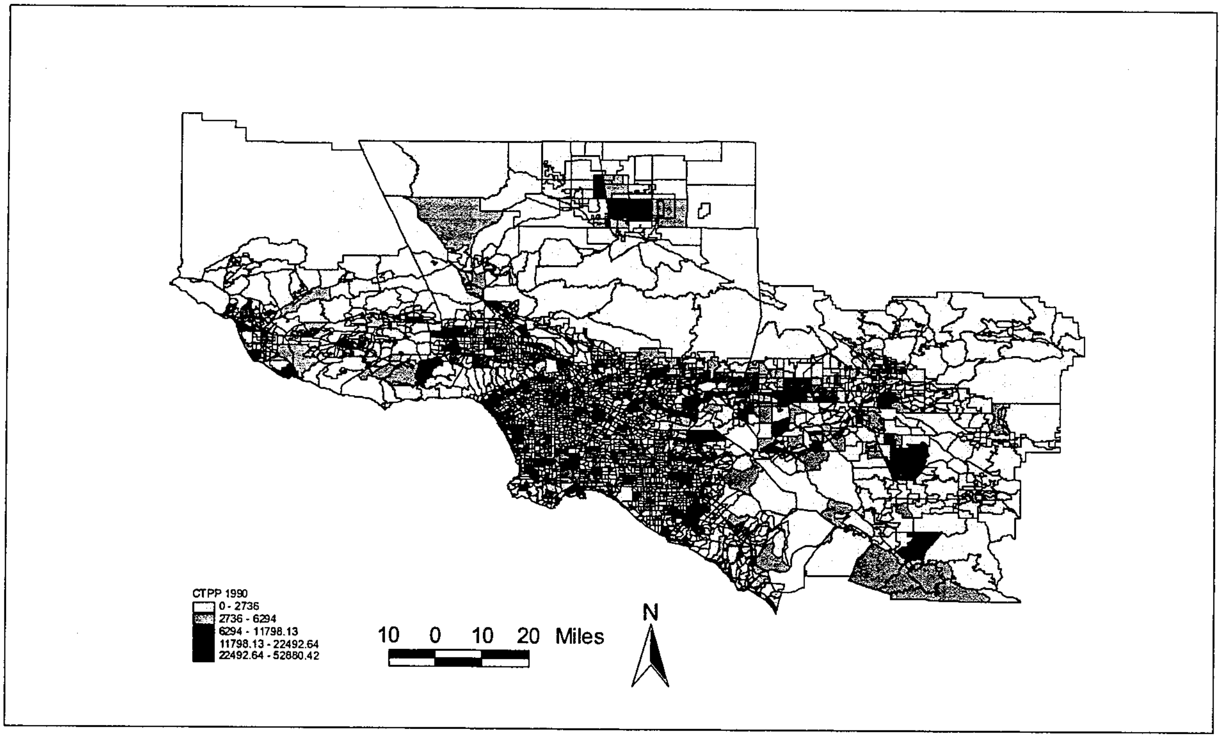

Figure 3.2 CTPP employment data in 1990 (4954 TAZs)

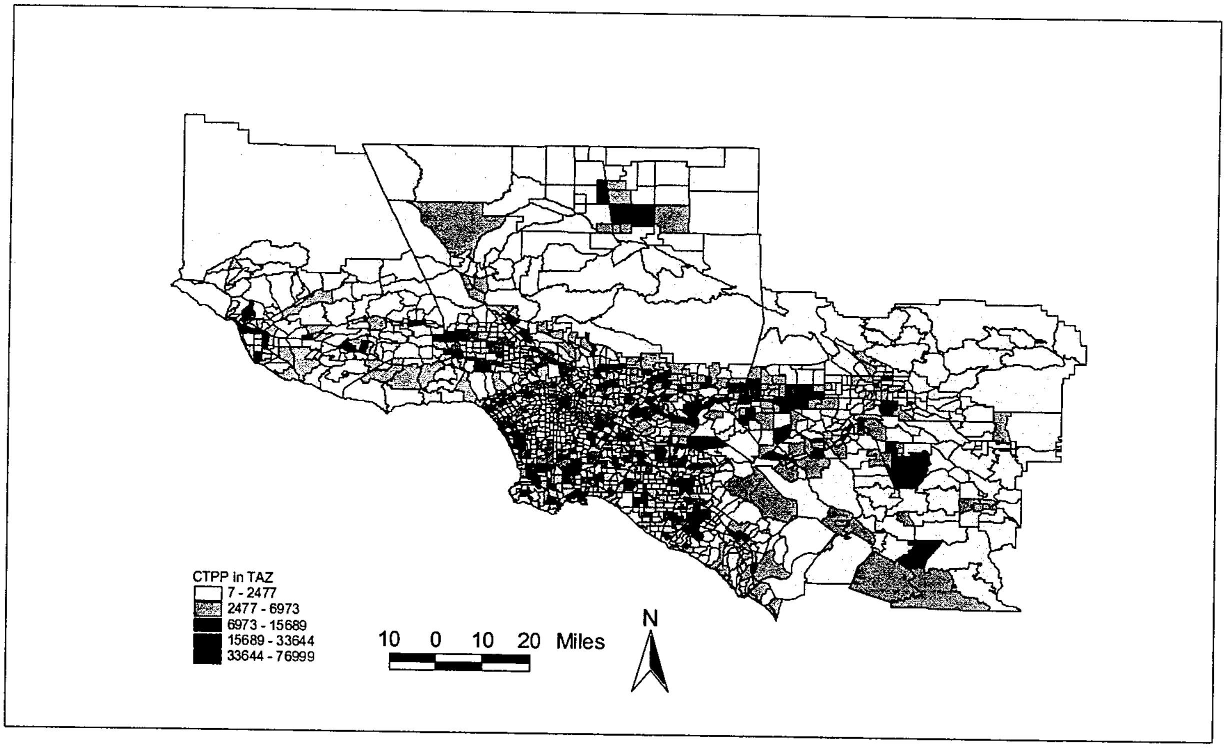

Figure 3.3 CTPP employment data in 1990 (1527 TAZs).

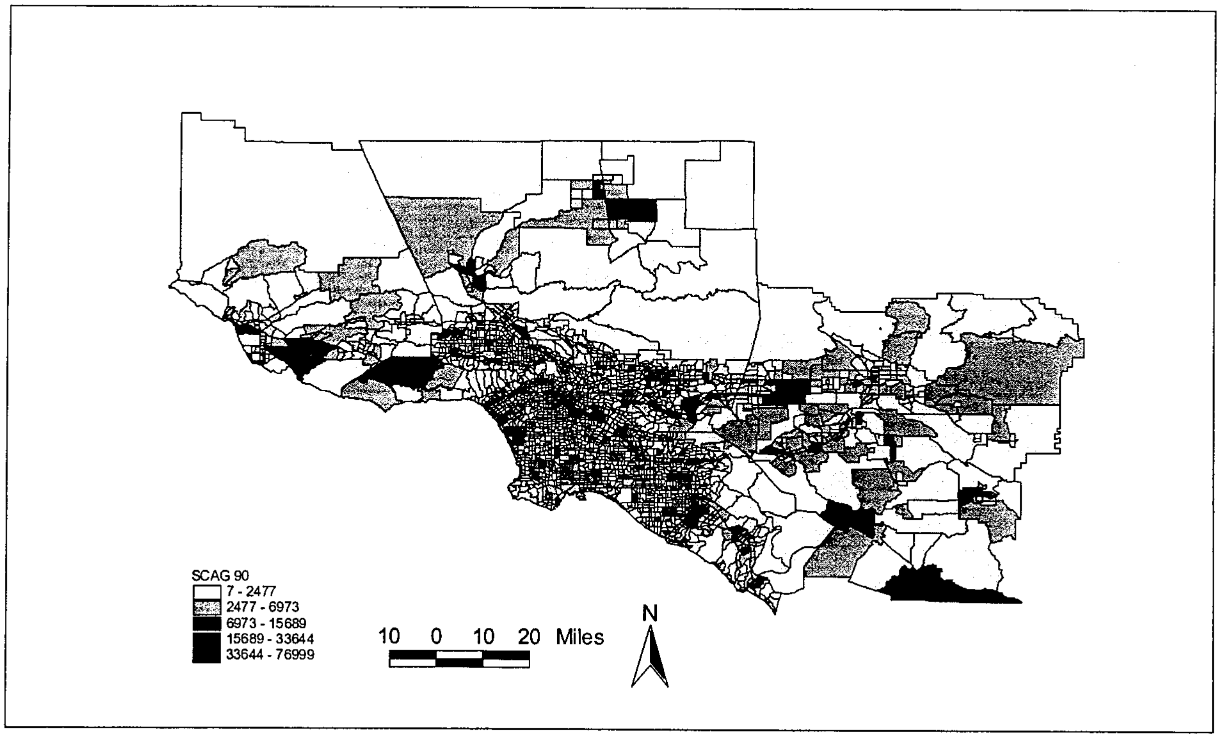

Figure 3.4 SCAG employment data in 1990 (2421 TAZs).

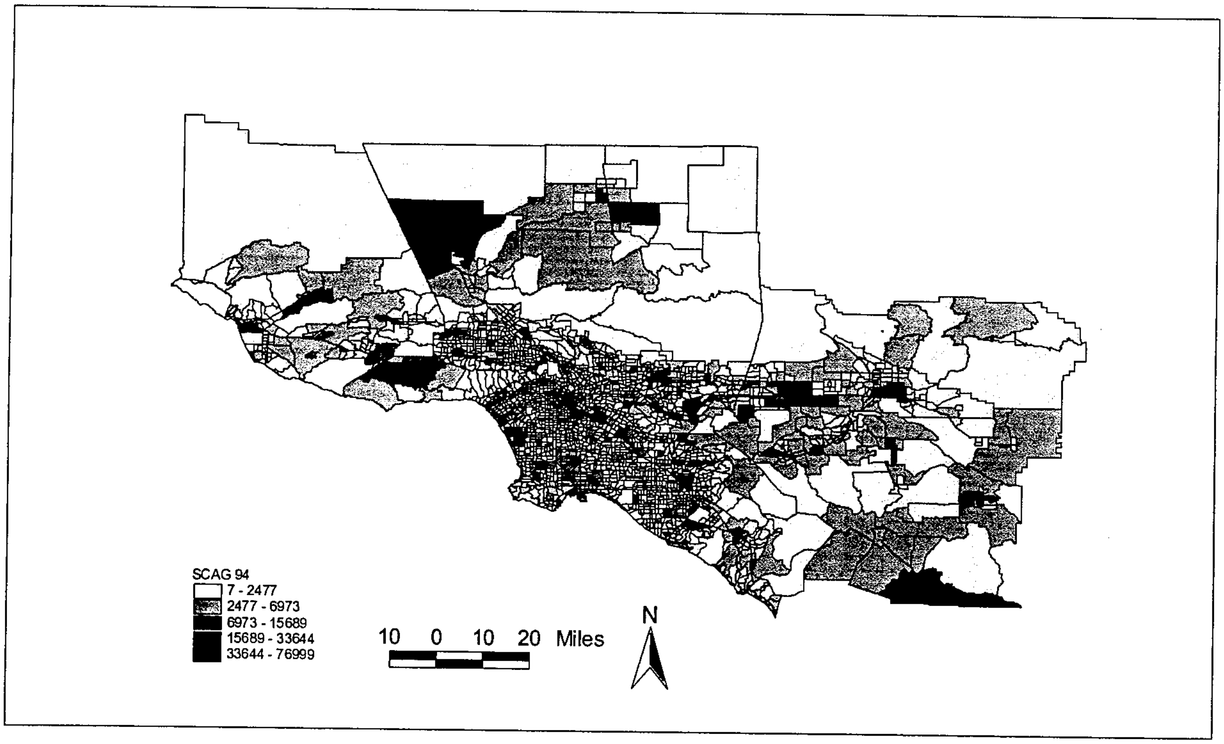

Figure 3.5 SCAG employment data in 1994 (2421 TAZs).

3.2. Seaports

The 1996 seaborne commerce data for the Long Beach and Los Angeles seaports were downloaded from the WCUS web site (http://www.wrsc.usace.army/mil/ndc/wcsc.htm). The WCUS data are tabulated by STCC categories. The first necessary step was to aggregate the classes of STCC commodities to the corresponding freight sectors used in this study. Four freight sectors, mining, durable manufacturing, non-durable (non-dur) manufacturing and unknown sectors, were used throughout. Table 3.1 shows the results for the aggregated sectors for international and domestic seaborne commerce.

Table 3.1 SEABORNE TRADE WEIGHT, LONG BEACH AND LOS ANGELES SEAPORTS, 1996

(Thousands of short tons)

		International				Domestic				
		Foreign		Canadian		Coastwise		Internal		
PORT	Sectors	Imports	Exports	Imports	Exports	Receipt	Shipments	Receipt	Shipments	Intraport
Long Beach	Mining	4,937	9,012	23	3	18,859	982	772	249	241
(TAZ# 603)	Durable	9,655	2,184	41	2	165	280	1	1	4
	Non-Dur	2,622	7,137	258	11	558	252	2	0	0
	UnKnown	50	57	0	36	0	0	0	0	0
Los Angeles	Mining	1,088	7,173	68	19	12,338	1,859	249	772	516
(TAZ# 564)	Durable	9,669	1,261	49	9	181	658	1	0	0
	Non-Dur	3096	4920	266	23	766	496	78	2	11
	UnKnown	65	46	0	5	0	1	0	0	0

Source: Waterborne Commerce of the United States (1996)

Note: Author aggregated STCC commodities to four sectors. Note that "International" is divided into "Foreign" and Canadian. Likewise, "Domestic" is divided into "Coastwise" and "Internal".

For the Port of Long Beach, the total cargo value in 1996 was $80.1 billion and the total tonnage was 58,395 thousand short tons; the dollar per ton value was approximately $1,372. This value was used to calculate the cargo value for each sector in each of the two ports. Table 3.2 lists the seaborne trade values of each sector at the two seaports.

Table 3.2 SEABORNE TRADE VALUE, LONG BEACH AND LOS ANGELES SEAPORTS, 1996

(Millions of dollars)

		International				Domestic				
		Foreign		Canadian		Coastwise		Internal		
PORT	Sectors	Imports	Exports	Imports	Exports	Receipt	Shipments	Receipt	Shipments	Intraport
Long Beach (TAZ# 603)	Mining	6,772	12,362	32	4	25,869	1,347	1,059	342	331
	Durable	13,244	2,996	56	3	226	384	1	1	5
	Non-Dur	3,597	9,790	354	15	765	346	3	0	0
	UnKnown	69	78	0	49	0	0	0	0	0
Los Angeles (TAZ# 564)	Mining	1,492	9,839	93	26	16,924	2,550	342	1,059	708
	Durable	13,263	1,730	67	12	248	903	1	0	0
	Non-Dur	4,247	6,749	365	32	1,051	680	107	3	15
	UnKnown	89	63	0	7	0	1	0	0	0

Source: Author calculation based on Table 3.1

Note: For the Port of Long Beach, total cargo value in 1996 is $80.1 billion (http://www.polb.com/cv.html), the cargo value is $ 1,372 per short ton. This dollar per ton value is applied to the Port Los Angeles.

Total imports by sector at each seaport were calculated by combining the international import and domestic receipts. Using the same procedure, the export by sector at each of the two seaports was derived from combining the international exports and domestic shipments. The internal intra-port values were ignored. The results are shown in Table 3.3.

Table 3.3 SEABORNE TRADE VALUE, LONG BEACH AND LOS ANGELES SEAPORTS, 1996

(Millions of dollars)

PORT	Sectors	Imports	Exports
Long Beach (TAZ# 603)	Mining	33,731	14,054
	Durable	13,528	3,384
	Non-Dur	4,719	10,151
	UnKnown	69	128
Los Angeles (TAZ# 564)	Mining	18,851	13,474
	Durable	13,580	2,645
	Non-Dur	5,769	7,463
	UnKnown	89	71

Source: Author calculation from Table 3.2

WCUS data do not include information on origins or destinations of the imported and exported goods. The origin and destination proportions of seaport commerce come from the SCAG Heavy Duty Truck Model and VMT Estimation (Table 3.4). Table 3.5 summarizes seaborne trade as well as job equivalents for each of the three major freight sectors.

Table 3.4 SEABORNE TRADE, LONG BEACH AND LOS ANGELES SEAPORTS, 1995

(Percent)

PORT	Import/Export	SCAG	Rail	Highway
Long Beach	Imports (Destinate to)	48.41%	41.00%	10.57%
	Exports (Origin from)	31.41%	40.99%	27.24%
Los Angeles	Imports (Destinate to)	55.21%	32.72%	12.05%
	Exports (Origin from)	35.81%	32.72%	31.06%

Source: SCAG Heavy Duty Truck Model Data Set (1998)

Notes: Ratio of the import/export freight originated from or destined to the SCAG region; 48.41% of imports at the Port Long Beach are destined to the SCAG region; 31.41% of exports at the Port Long Beach originated from the SCAG region.

Table 3.5 SEABORNE TRADE SUMMARY, LONG BEACH AND LOS ANGELES SEAPORTS, 1996

PORT	Sectors	Imports				Exports				Total
		Goods value (M$) *1	To SCAG (M$) *2	$/Job *3	Job equiv. Dest for SCAG *4	Goods Value (M$) *1	From SCAG (M$)*2	$/Job *3	Job equiv. Origin from SCAG *4	Inbound outbound job equiv. *5
Long Beach (TAZ# 603)	Mining	33,731	16,330	134,590	121,331	14,054	4,414	134,590	32,795	154,126
	Durable	13,528	6,549	107,726	60,793	3,384	1,063	107,726	9,865	70,658
	Non-Dur	4,719	2,284	133,556	17,104	10,151	3,188	133,556	23,869	40,973
	UnKnown	69	33			128	40			
Los Angeles (TAZ# 564)	Mining	18,851	10,407	134,590	77,326	13,474	4,825	134,590	35,849	113,175
	Durable	13,580	7,497	107,726	69,593	2,645	947	107,726	8,791	78,384
	Non-Dur	5,769	3,185	133,556	23,848	7,463	2,673	133,556	20,011	43,859
	UnKnown	89	49			71	26			

Source: Author calculation

Note: Data from various sources:

1. Value imported from Table 3.3
2. Value calculated from the production of goods total and the percentage of goods from/to SCAG region in Table 3.4
3. Author calculation, based on RSRI I/O model, using the PC-IO package
4. Job equivalents for SCAG destined freight and job equivalents for SCAG originated freight. Calculated by multiplying the value of goods from/to SCAG region and $ per job.
5. Inbound and outbound job equivalent. Sum of jobs for import goods and jobs for export goods.

3.3. Airports

According to the report, *Air Cargo in SCAG Region* (SCAG, 1992), the allocations of air cargo to the five major airports in SCAG region are: LAX 79.1%, Ontario 17.8%, Long Beach 1.7%, and John Wayne 0.2%. The total tonnage of air cargo in LAX and Ontario were downloaded from the various airport web pages. The cargo tonnages of the other three airports were calculated on the basis of their cargo shares. The tonnage of the air cargo is listed in Table 3.6.

Table 3.6 TOTAL AIR CARGO INCLUDING MAIL, MAJOR AIRPORTS IN SCAG REGION

(Cargo Tons)

AIRPORT	TAZ	Percent*	1991	1996	1998
Ontario	1007	17.80%	282,558	437,139	454,231
LAX	485	79.10%	1,258,209(mail 162,840)	1,895,754(mail 194,091)	2,051,873
Burbank	288	1.20%	19,082	28,890	31,035
Long Beach	583	1.70%	27,043	40,928	43,967
John Wayne	1265	0.20%	3,180	4,815	5,173
Total		100%	1,590,764	2,407,526	2,586,279

Source: Airport Statistics Report.
http://www.lawa.org/lax/html/cargo.htm
http://www.lawa.org/ont/html/statistics.htm
Percentages are stated in SCAG report, Air Cargo in SCAG Region (SCAG, 1992).

*Notes: The total cargo tonnages of Ontario and LAX airport are obtained directly from airport statistics.
Cargo tonnages of Airport Burbank, Long Beach and John Wayne are calculated from the percentage cited in SCAG's *Air Cargo in SCAG Region* (1992).
LAX (79.1 percent), Ontario International (17.8 percent), Long Beach (1.7 percent), Burbank (1.2 percent), John Wayne (0.2 percent)". Same Ratios are applied to 1991, 1996 and 1998.

Data on air cargo at LAX (http://www.lawa.org/lax/html/cargo.htm) show that fifty percent of air cargo activities is international in origin or destination. Another data source on LAX air cargo, (http://web3.asia1.com.sg/timesnet/data/cna/docs/cna1775.html), corroborates that imports and exports of air cargo are almost equal at LAX. The same ratio is assumed for other airports. The results are presented in Table 3.7.

Table 3.7 AIR CARGO IMPORT AND EXPORT, MAJOR AIRPORTS IN SCAG REGION, 1996

(Cargo Tons)

AIRPORT	TAZ	1996	Import*		Export*	
			Foreign	Domestic	Foreign	Domestic
Ontario	1007	437,139	109,285	109,285	109,285	109,285
LAX	485	1,895,754	473,939	473,939	473,939	473,939
Burbank	288	28,890	7,223	7,223	7,223	7,223
Long Beach	583	40,928	10,232	10,232	10,232	10,232
John Wayne	1265	4,815	1,204	1,204	1,204	1,204
Total		2,407,526	601,882	601,882	601,882	601,882

Source: Author calculation based on Table 3.6.

*Notes: Imports and exports of air cargo are almost equal tonnage at LAX. This ratio is applied to the other airports. (http://web3.asia1.com.sg/timesnet/data/can/docs/cna1775.html)
The proportions of international and domestic cargo come from LAX airport statistics (http://www.lawa.org/lax/html/cargo.htm).
From the LAX report, fifty percent of air cargo activity is international in origin or destination. The same percentage is assumed for the other regional airports.

The data on LAX (http://www.lawa.org/lax/html/cargo.htm) indicate that the top regional trading partner, Asia-Pacific, accounts for a total of 448,000 tons valued at $43 billion; the second, Europe, has a total of 141,000 tons valued at $11.2 billion. It is estimated that the dollar per ton value for the air cargo at LAX is about $92,020 per ton (($43 billion + $11.2 billion) / (448000 + 141000)). This dollar per ton value is applied to the air cargo at other local airports. The values of the air cargo for each airport are calculated by multiplying cargo tonnage by dollar per ton value ($92,020 per ton). The results are listed in Table 3.8.

Table 3.8 AIR CARGO VALUE, MAJOR AIRPORTS IN SCAG REGION, 1996

(Millions of dollars)

AIRPORT	TAZ#	All trade	Import		Export	
			Foreign	Domestic	Foreign	Domestic
Ontario	1007	40,226	10,056	10,056	10,056	10,056
LAX	485	174,447	43,612	43,612	43,612	43,612
Burbank	288	2,658	665	665	665	665
Long Beach	583	3,766	942	942	942	942
John Wayne	1265	443	111	111	111	111
Total		221,541	55,385	55,385	55,385	55,385

Source: Author calculation. Cargo value is $92,020 per ton, calculated from LAX airport statistics. (http://www.lawa.org/lax/html/cargo.htm)

There is no direct information on the sector shares for air cargo. Estimates were obtained from the 1993 Commodity Flow Survey for the U.S.; CFS includes the values and tonnage shares of durable and non-durable (non-dur) manufacturing for air cargo in U.S (Table 3.16). The results are shown in Table 3.9.

Table 3.9 AIRBORNE TRADE SUMMARY, MAJOR AIRPORTS IN SCAG REGION, 1996

		Imports					Exports					Total Inbound outbound job equiv. *6
	Sectors	Weight (ktons)*1	Value (M$) *2	To SCAG (M$)*3	$/Job *4	Job equiv. dest for SCAG*5	Weight (ktons)*1	Goods Value (M$)*2	From SCAG (M$)*3	$/Job *4	Job equiv. origin from SCAG*5	
AIRPORT												
Ontario	Durable	204	17,748	4,437	107,726	41,187	204	17,748	4,437	107,726	41,187	82,374
	Non-Dur	15	2,365	591	133,556	4,427	15	2,365	591	133,556	4,427	8,855
	Total	219	20,113	5,028		45,614	219	20,113	5,028		45,614	91,228
LAX	Durable	885	76,966	19,242	107,726	178,616	885	76,966	19,242	107,726	178,616	357,232
	Non-Dur	63	10,257	2,564	133,556	19,200	63	10,257	2,564	133,556	19,200	38,401
	Total	948	87,224	21,806		197,816	948	87,224	21,806		197,816	395,632
Burbank	Durable	13	1,173	293	107,726	2,722	13	1,173	293	107,726	2,722	5,444
	Non-Dur	1	156	39	133,556	293	1	156	39	133,556	293	585
	Total	14	1,329	332		3,015	14	1,329	332		3,015	6,029
Long Beach	Durable	19	1,662	415	107,726	3,856	19	1,662	415	107,726	3,856	7,712
	Non-Dur	1	221	55	133,556	415	1	221	55	133,556	415	829
	Total	20	1,883	471		4,271	20	1,883	471		4,271	8,541
John Wayne	Durable	2	195	49	107,726	454	2	195	49	107,726	454	907
	Non-Dur	0	26	7	133,556	49	0	26	7	133,556	49	98
	Total	2	222	55		502	2	222	55		502	1,005
Airport Total	Durable	1,124	97,744	24,436	107,726	226,835	1,124	97,744	24,436	107,726	226,835	453,669
	Non-Dur	80	13,026	3,257	133,556	24,384	80	13,026	3,257	133,556	24,384	48,767
	Total	1,204	110,770	27,693		251,218	1,204	110,770	27,693		251,218	502,436

Source: Author calculation

1. From Table 3.7
2. From Table 3.8
3. Calculated from the production of goods value and the percentage of goods from/to SCAG region as a quarter of the total imports and exports.
4. Author calculation, based on RSRI I/O model, using PC-IO package
5. Job equivalents for SCAG destined freight and job equivalents for SCAG originated freight. Calculated from the value of goods from/to SCAG region and dollars per job.
6. Job equivalents for the sum of imports and exports.

3.4. Rail

The ITMS GIS-Based package provides information on freight entering and leaving the SCAG region via rail at eight external zones (entry points). Using GIS-base maps (Figure 7), the percentages of STCC sectors for inbound and outbound goods at each external station are extracted from the database file. This procedure was followed because ITMS did not identify freight traffic by rail yards (see the Freight Trip Generation section in Part 5, Network Analysis). The STCC sectors were aggregated into four freight-carrying sectors: transportation & utilities, mining, durable manufacturing, non-durable (non-dur) manufacturing. The results for the eight entry-points are shown in Tables 3.10 and 3.11.

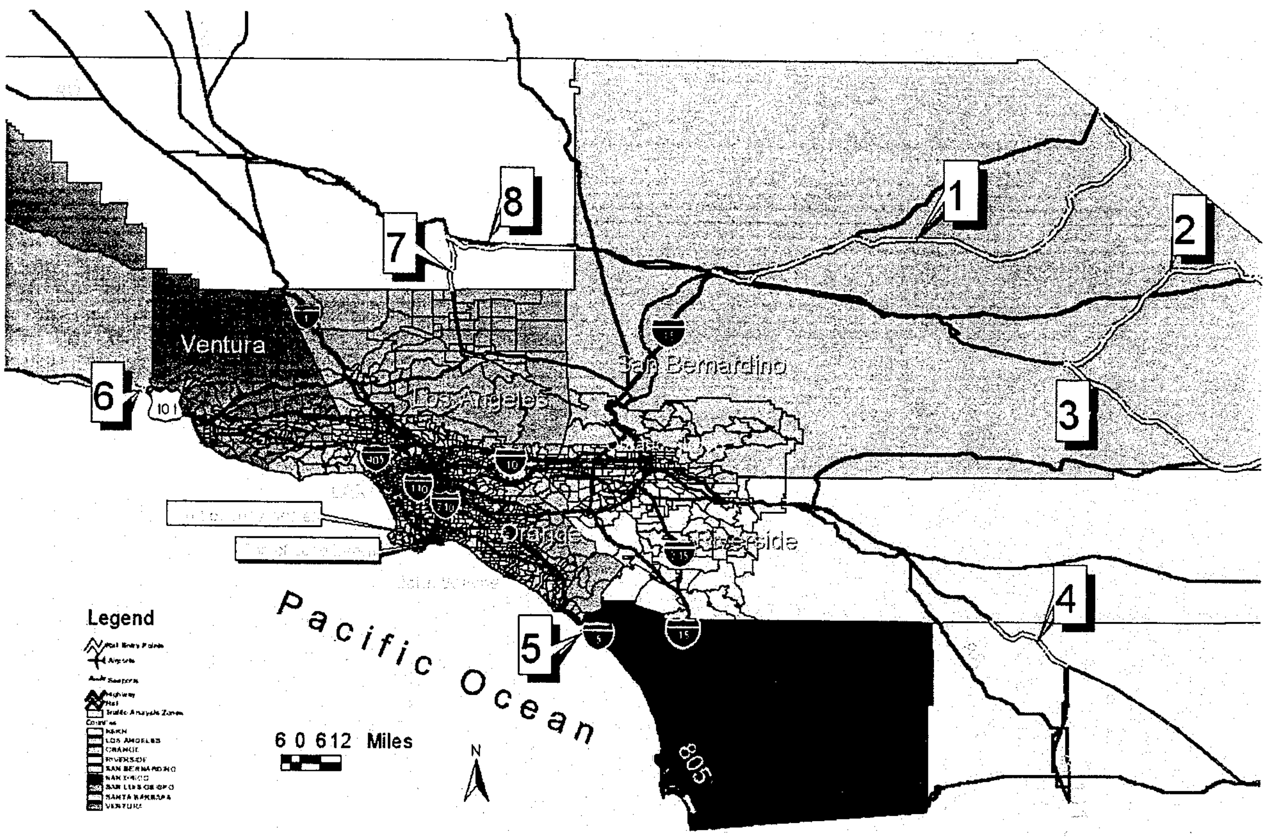

Figure 3.6 Rail entry points at the boundary of SCAG region.

Table 3.10 INBOUND AND OUTBOUND RAIL GOODS, ITMS 1996

	Inbound (percent)					Outbound (percent)				
ENTRY ZONES	Weight (tons)	Trans-Util	Non-Dur	Mining	Durable	Weight (tons)	Trans-Util	Non-Dur	Mining	Durable
1	36247155	0.345	0.3263	0.158	0.1706	525216	0.0207	0.9653	0.0037	0.0104
2	36247155	0.345	0.3263	0.158	0.1706	525216	0.0207	0.9653	0.0037	0.0104
3	36247155	0.345	0.3263	0.158	0.1706	525216	0.0207	0.9653	0.0037	0.0104
4	27834822	0.441	0.3512	0.0206	0.1875	12503187	0.1933	0.5251	0.0248	0.2569
5	61448	0.0777	0.5382	0	0.3841	0	0	0	0	0
6	1246561	0.0786	0.7	0.0454	0.176	2285815	0.1935	0.6876	0.0068	0.1121
7	17845080	0.1216	0.4567	0.191	0.2307	7374396	0.1794	0.6402	0.007	0.1703
8	17845080	0.1216	0.4567	0.191	0.2307	7374396	0.1794	0.6402	0.007	0.1703

Source: Author calculation from ITMS 1996.

Table 3.11 RAIL FREIGHT IN SCAG REGION, ITMS 1996

(Tons)

In-bound		TOTAL	Trans-Util	Non-dur	Mining	Durable
	1	36,243,530.28	12505268	11827447	5727050	6183765
	2	36,243,530.28	12505268	11827447	5727050	6183765
	3	36,243,530.28	12505268	11827447	5727050	6183765
	4	27,843,172.45	12275157	9775589	573397.3	5219029
	5	61,448.00	4774.51	33071.31	0	23602.18
	6	1,246,561.00	97979.69	872592.7	56593.87	219394.7
	7	17,845,080.00	2169962	8149848	3408410	4116860
	8	17,845,080.00	2169962	8149848	3408410	4116860
	Total	173,571,932.00	54233640	62463290	24627963	32247040
	%	100	31.24563	35.98698	14.18891	18.57849

Out-bound		TOTAL	Trans-Util	Non-Dur	Mining	Durable
	1	525,268.52	10871.97	506991	1943.299	5462.246
	2	525,268.52	10871.97	506991	1943.299	5462.246
	3	525,268.52	10871.97	506991	1943.299	5462.246
	4	12,504,437.32	2416866	6565423	310079	3212069
	5	0.00	0	0	0	0
	6	2,285,815.00	442305.2	1571726	15543.54	256239.9
	7	7,351,535.37	1322967	4721088	51620.77	1255860
	8	7,351,535.37	1322967	4721088	51620.77	1255860
	Total	32,469,486.00	4522462	25038063	124615	2784346
	%	100	13.92834	77.1126	0.383791	8.575269

Source: Author calculation from ITMS (1996)

ITMS data do not include information on the origins or destinations of the outbound or inbound goods delivered by rail. This information was gathered from the 1996 SCAG Inter-regional Goods Movement Study. To be consistent, the total tonnage of goods also relies on data from the SCAG Inter-regional Goods Movement Study. The shares of sectors relied on the ITMS percentages for inbound and outbound goods by rail. There are no available dollar per ton values for goods by sectors via rail. These were calculated from the 1993 Commodity Flow Survey for California. The dollar per ton values for the four sectors are listed in Table 3.16. Tonnages of goods in and out of SCAG region by rail were then converted to the values of goods moved (Table 3.12).

Table 3.12 SUMMARY OF RAIL FREIGHT TO AND FROM THE SCAG REGION

Rail (ITMS, 1992)

		$/ton	Total in (ktons)	Total in (M$)				Total out (ktons)	Total out (M$)				
Rail	Mining	216.29	24,628	5,327				125	27				
total	Durable	510.60	32,247	16,465				2,784	1,422				
	Non-Dur	571.53	62,463	35,700				25,038	14,310				
	Trans-Util	110.68	54,234	6,002				4,522	501				
			173,572					32,469					

Rail (SCAG, 1995)

		$/ton	SCAG dest (ktons)		SCAG dest (M$)	$/Job	Job equiv. dest for SCAG	SCAG origin (ktons)		M$	$/Job	Job equiv. origin from SCAG	Total (jobs)
Rail	Mining	216.29	13,536		2,928	134,590	21,754	159		34	134,590	255	22,009
total	Durable	510.60	17,724		9,050	107,726	84,008	3,550		1,813	107,726	16,827	100,835
	Non-Dur	571.53	34,332		19,622	133,556	146,917	31,925		18,246	133,556	136,617	283,534
	Trans-Util	110.68	29,808		3,299	99,713	33,086	5,766		638	99,713	6,400	39,487
			95,400				285,765	41,400				160,100	445,865

Source: Author calculation based on ITMS 1996 and SCAG Inter-Regional Goods Movement Study, 1996.

3.5. Highways

CalTrans' ITMS GIS-Based package provided information on freight in and out of the SCAG region via major highways. After finding twelve regional entry points on GIS-base maps (Figure 8), the percentages of STCC sectors for inbound and outbound goods at each external station were extracted from the database file. The STCC sectors were then aggregated into the four freight sectors: transportation & utilities, mining, durable manufacturing, non-durable (non-dur) manufacturing. The results are shown in Tables 3.13 and 3.14.

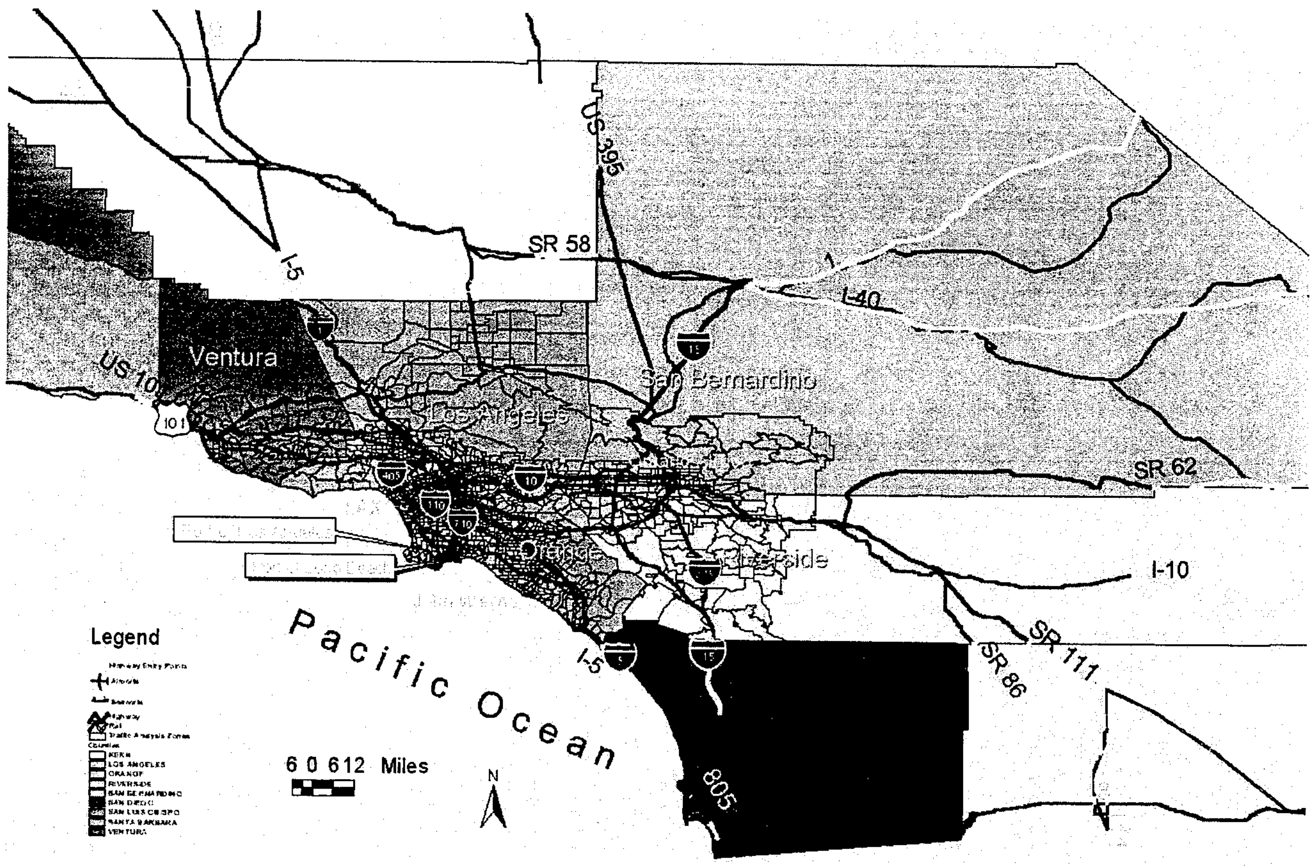

Figure 3.7 Highway entry points at the boundary of SCAG region.

Table 3.13 INBOUND AND OUTBOUND HIGHWAY GOODS MOVEMENT, SCAG REGION, 1996

	Inbound (percent)					Outbound (percent)				
ENTRY POINTS	Weight (tons)	Trans -Util	Non -Dur	Mining	Durable	Weight (tons)	Trans -Util	Non- Dur	Mining	Durable
I-40 E	0	0	0	0	0	0	0	0	0	0
SR 62 E	0	0	0	0	0	0	0	0	0	0
SR 111 S	0	0	0	0	0	0	0	0	0	0
I-5 N	40,714,747	0.15	0.37	0.23	0.23	61,098,488	0.23	0.38	0.13	0.24
I-10 E	32,684,181	0.22	0.31	0.26	0.21	7,541,156	0.19	0.26	0.39	0.15
I-15 N	13,110,722	0.03	0.25	0.6	0.12	3,271,886	0.23	0.37	0	0.39
SR 86 SE	853,243	0.31	0.53	0	0.17	1,787,755	0	0.55	0.35	0.11
US 101 NW	19,687,198	0.24	0.37	0.09	0.28	25,565,131	0.32	0.36	0.07	0.22
US 395 N	3,749,224	0.09	0.48	0.19	0.23	2,767,748	0.04	0.53	0.1	0.31
I-5 S	12,977,659	0.25	0.2	0.36	0.17	28,991,141	0.28	0.26	0.23	0.21
I-15 S	1,123,539	0.5	0.22	0	0.28	4,530,346	0.02	0.36	0.43	0.21
SR 58 W	3,231,133	0.03	0.78	0	0.19	3,161,859	0.05	0.74	0.01	0.18

Source: Author calculation from ITMS 1996.

Table 3.14 HIGHWAY FREIGHT IN AND OUT, SCAG REGION, 1996

(Tons)

Inbound		TOTAL	Trans-Util	Non-Dur	Mining	Durable
	I-40 E	0	0	0	0	0
	SR 62 E	0	0	0	0	0
	SR 111 S	0	0	0	0	0
	I-5 N	39900452.1	6107212.05	15064456	9364392	9364392
	I-10 E	32684181	7190519.82	10132096	8497887	6863678
	I-15 N	13110722	393321.66	3277681	7866433	1573287
	SR 86 SE	861775.43	264505.33	452218.8	0	145051.3
	US 101 NW	19293454	4724927.52	7284263	1771848	5512415
	US 395 N	3711731.76	337430.16	1799628	712352.6	862321.5
	I-5 S	12718105.8	3244414.75	2595532	4671957	2206202
	I-15 S	1123539	561769.5	247178.6	0	314590.9
	SR 58 W	3231133	96933.99	2520284	0	613915.3
		126,635,094	22921034.8	43373337	32884870	27455853
Outbound		**TOTAL**	**Trans-Util**	**Non-Dur**	**Mining**	**Durable**
	40E	0	0	0	0	0
	62E	0	0	0	0	0
	10E	0	0	0	0	0
	111S	59876518.2	14052652.2	23217425	7942803	14663637
	86S	7465744.44	1432819.64	1960701	2941051	1131173
	15S	3239167.14	752533.78	1210598	0	1276036
	5S	1805632.55	0	983265.3	625714.3	196653.1
	101N	24798177.1	8180841.92	9203447	1789559	5624329
	5N	2712393.04	110709.92	1466906	276774.8	858001.9
	58W	28411318.2	8117519.48	7537697	6667962	6088140
	395N	4620952.92	90606.92	1630925	1948049	951372.7
	15N	3098621.82	158092.95	2339776	31618.59	569134.6
		136,028,525	32895776.9	49550740	22223532	31358477

Source: Author calculation from ITMS (1996)

ITMS data do not include information about the origins or destinations of the outbound or inbound goods movements. This information was obtained from the 1996 SCAG Inter-regional Goods Movement Study. To be consistent, the total tonnage of goods also relied on data from the same SCAG Inter-regional Goods Movement Study. The shares allocated to sectors used the ITMS percentage for inbound and outbound goods via highways. There were no available dollar per ton values for the various sectors carried on the highways. These were also calculated from the 1993 Commodity Flow Survey for California and are displayed in Table 3.16. The tonnages of goods in and out of SCAG region via highway were converted to the value of goods moved (Table 3.15).

Table 3.15 SUMMARY OF HIGHWAY FREIGHT MOVEMENTS IN AND OUT, SCAG REGION

Truck (ITMS, 1992) *4

		$/ton	Total in (ktons)	Total in (M$)				Total out (ktons)	Total out (M$)				
Truck	Mining	25.37	32,885	834				22,224	564				
Total	Durable	1410.49	27,456	38,726				31,358	44,231				
	Non-Dur	908.87	43,373	39,421				49,551	45,035				
	Trans_ Util	384.36	22,921	8,810				32,896	12,644				
			126,635					136,029					

Truck (SCAG, 1995) *6

		$/ton	SCAG Dest (ktons)		M$	$/Job	Job equiv. dest for SCAG	SCAG Origin (ktons)		M$	$/Job	Job equiv. origin from SCAG	Total (jobs)
Truck	Mining	25.37	62,609		1,589	134,590	11,804	38,442		975	134,590	7,247	19,051
Total	Durable	1410.49	52,273		73,731	107,726	684,427	54,243		76,510	107,726	710,225	1,394,652
	Non-Dur	908.87	82,578		75,053	133,556	561,962	85,712		77,902	133,556	583,288	1,145,250
	Trans_ Util	384.36	43,639		16,773	99,713	168,216	56,903		21,871	99,713	219,342	387,557
			241,100				1,426,408	235,300				1,520,102	2,946,511

3.6. Economic Activities

(1) Dollar per ton values

To convert dollar values to tonnage of freight, dollar per ton factors were needed. But there are no such data for the four sectors for the local region by mode. It was possible to calculate these values from the 1993 Commodity Flow Survey for California and the U.S. Table 3.16 shows the results.

Table 3.16 DOLLAR/TON VALUE OF SELECTED COMMODITIES, 1992

(Part 1. U.S.)

US	Mining			Durable			Non-Dur			Trans-Util		
	(M$)	(kton)	($/ton)	(M$)	(kton)	($/ton)	(M$)	(kton)	($/ton)	(M$)	(kton)	($/ton)
Air	0	0		3114	14	222,428.6	415	1	415,000	7	0	
Truck	32,592	1,705,016	19	1,821,219	1,210,872	1,504	2,200,551	2,612,081	842	89,799	117,397	765
Inland	2,253	91,380	25	1,530	3,063	500	34,699	231,967	150	292	2,222	131
Sea	0	0		0	0		1	0		0	0	
Parcel	831	16	51,938	385,191	9,172	41,996	125,402	5,642	22,227	3,556	72	49,389
Rail	18,310	829,039	22	84,749	121,938	695	135,671	562,390	241	3,124	28,933	108
Pipe	0	0		0	0		85,689	449,014	191	0	0	
sum	53,986	2,625,451	21	2,295,803	1,345,059	1,707	2,582,428	3,861,095	669	96,778	148,624	651

(Part 2. California)

CAL	Mining			Durable			Non-Dur			Trans-Util		
	(M$)	(kton)	($/ton)	(M$)	(kton)	($/ton)	(M$)	(kton)	($/ton)	(M$)	(kton)	($/ton)
Air	0	0		778	3	259,333.3	0	0	0	0	0	
truck	3,284	129,425	25	186,464	132,198	1,410	215,766	237,399	909	4,695	12,215	384
inland	0	0		0	0		0	0		0	0	
sea	0	0		0	0		0	0		0	0	
parcel	2	0		68,669	950	72,283	16,297	533	30,576	195	3	65,000
Rail	223	1,031	216	1,252	2,452	511	5,445	9,527	572	142	1,283	111
Pipe	0	0		0	0		13,947	71,487	195	0	0	
Sum	3,509	130,456	27	257,163	135,603	1,896	251,455	318,946	788	5,032	13,501	373

Source: Author calculation Based on 1993 Commodity Flow Survey for U.S. and California.

Table 3.17 TRANSACTION TABLE , 1990

(Millions of dollars)

		1	2	3	…	15	16	17	Sum of interm	HHs	Others	Local suppl	Local demand	Import	Export	Total output
1	Agriculture	894.7	0.2	0	…	8.2	28.9	363.1	3061.1	575	320.4	3956.5	8981.9	5025.4	11802	15758.5
2	Mining	7	49.6	0	…	0.6	4	314.9	4626.3	9.1	0	4635.4	24629.9	19994.5	158.5	4793.9
3	Construction	98.5	193.4	35.5	…	72.2	438.8	9965	16738.7	272.8	191.1	17202.6	23529.1	6326.5	2002.6	19205.2
4	Manufacturing (nondurable)	1287	54.3	12	…	215.2	1786	7053	40703.1	13937	1495.3	56135.6	85791	29655.4	26173	82308.3
5	Manufacturing (durable)	152.5	154.4	82.3	…	84	410	4828	27337.8	4982.1	19987	52307	95668.1	43361.1	37596	89902.9
6	Transportation	108.1	13.3	47.2	…	53.5	500.2	1259	6446.4	912.1	1833.4	9191.9	19220.5	10028.6	10214	19405.6
7	Communications and utilities	96.2	79.6	24	…	82.5	740.5	14134	25567	4813.9	1820.3	32201.2	59132.6	26931.4	8382.5	40583.7
8	Wholesale trade	686.7	34.6	274.3	…	47.4	256	2269	12956.3	4448.1	9073.4	26477.8	29634.7	3156.9	19394	45872.1
9	Retail	89.4	44.6	294	…	95.2	1041	2019	10188.9	22017	17	32223.2	36921.2	4698	25895	58118.4
10	F.I.R.E.	488.8	475.8	173.5	…	665.6	2136	1780	28390.7	27664	11147	67201.7	108274	41072.3	15438	82639.7
11	Business services	182.9	60.1	347.8	…	224	2364	4339	23980.4	3580.8	3951.3	31512.5	44883.2	13370.7	5504.6	37017.1
12	Personal services	8.7	4	21.5	…	9	270.2	220.6	1787	2610.4	1357.9	5755.3	9359.9	3604.6	3268.8	9024.1
13	Entertainment and recreation	42.2	0.8	0.1	…	25.9	60.1	60.5	5489.7	2493.3	3725.8	11708.8	17069.8	5361	19808	31516.9
14	Health	30.7	0	0	…	0.8	3.2	13.7	723.6	2824.6	24022	27570	29087.4	1517.4	3048.2	30618.2
15	Educational services	2	0.9	0	…	1	4.4	33.8	129.1	2227.4	1474.8	3831.3	4497.7	666.4	903.2	4734.5
16	Professional and related	88.9	137.7	55.3	…	94.8	2165	10391	24346.3	6097.6	13444	43887.5	48496.7	4609.2	14168	58055.8
17	Government	54	38.4	27.7	…	20.6	295.6	713.9	3483.4	3069.3	118887	125439.8	138154.1	12714.3	20032	145471.8
18	Sum of intermediate	4323	1346	1397	…	1708	12599	59933	0	0	0	0	0	0	0	0
	Wages, salaries, & proprietors	2194	737.2	9449	…	2227	21480	28107	0	0	0	0	0	0	0	0
	S&I taxes	376.7	167.3	463.1	…	101.6	1041	0	0	0	0	0	0	0	0	0
	Federal tax	5472	2023	325.8	…	211.5	9100	46850	0	0	0	0	0	0	0	0
	Remainders	3393	520	7570	…	487.1	13836	10582	0	0	0	0	0	0	0	0
	Total output ($M)	15758	4794	19205	…	4734	58056	1E+05	0	0	0	0	0	0	0	0

Source: From the transaction table calculated by Cho (1999).

(2) Transactions table

In regional economic analysis, a transactions table is often used to depict regional interindustry activities. These imply freight movements from one industry to another. The 1990 transactions table for the local region (Table 3.17) is calculated from the RSRI's PC-IO package. The major drawback of the transactions table is that it does not include spatial information. In Part 4, we elaborate on how interindustry shipments were allocated to TAZs.

(3) Dollar per job

The PC-IO package also generates the employment, wages, and output for each of 515 sectors. These can be aggregated to the 17 sectors we used in this study. The dollars per job can be generated directly, dividing output by employment. The results are shown in Table 3.18.

Table 3.18 DOLLARS PER JOB BY MAJOR SECTOR, SCAG REGION, 1990

		Employment (1,000 jobs)	Wages (M$)	Output (M$)	Wage ($/job)	Output ($/job)
1	Agriculture	145.7	2230.1	20000	15306.1	137268.4
2	Mining	74.3	3152.5	10000	42429.3	134589.5
3	Construction	397.7	10652.6	15078.3	26785.4	37913.6
4	Manufacturing (Nondurable)	1018.3	27426.7	136000	26933.8	133555.9
5	Manufacturing (Durable)	2051.5	65649.7	221000	32000.8	107726.1
6	Transportation	66.3	2094.3	5590.8	31611.3	84388.7
7	Communications and Utilities	98	3414.4	10792.1	34859.1	110179.7
8	Wholesale Trade	19.9	567.5	2000	28517.6	100502.5
9	Retail	164.5	3362	8825	20436.4	53644.2
10	F.I.R.E.	53.2	2174	7000	40864.7	131578.9
11	Business Services	390.4	7402.4	15378.1	18963.6	39395.7
12	Personal Services	174.2	2093.8	5000	12019.5	28702.6
13	Entertainment and Recreation	150.8	3453.4	8000	22900.5	53050.4
14	Health	80	2360.3	4000	29503.8	50000
15	Educational Services	81.1	1355.9	3000	16718.9	36991.4
16	Professional and Related	306.5	7421	17248	24215.4	56282
17	Government	111.4	2352.3	6000	21115.8	53860

Source: Author calculation based on RSRI I/O model and PC-IO package

4. Data Integration

Traditional transactions table data indicate shipments from one sector to another but do not specify where the shipments come from and where they are destined. A major task of this research was to add spatial detail to these interindustry shipments.

The CTPP and SCAG employment data are available by major sector and by census tract or traffic analysis zone so that they contain the spatial location of all regional jobs. Specific sites like seaports, airports, rail yards and highway entry points for freight to move in and out of the region are also identified by TAZ. It is reasonable to combine these three data sets to understand not only how freight moves between industry sectors, but also how freight moves between spatial locations.

4.1. Methodology

In a Leontief input-output model, each sector's total product is the sum of the total intermediate use by all industrial sectors and shipments to final users. Final use includes investment, household consumption, and exports. Similarly, total supply is the sum of total production and the imports of goods. The imports and exports denoted in a regional input-output model do not include any spatial detail except for the obvious fact that they are outside the region. There is no information on where the import and exports come from and where are they going. But for purposes of calculating freight trips produced and attracted, it is useful to itemize and specify how the imports and exports do pass through specific entry points, like seaports, airports, rail yards and the external zones of highway entry points.

In order to add spatial detail to the freight movements, the aspatial regional transactions table is disaggregated and assigned to each traffic analysis zone (TAZ) to identify where the various shipments come from and where they are going. As the CTPP employment data do include spatial information, these can be used as a spatial factor to locate the attraction and production of freight or freight related jobs in each TAZ (see Equations 1 and 2).

But before proceeding this way, the imports and exports in the transaction table had to be set aside to avoid double-counting. Since the imports and exports always happen at specific sites, like seaports, airports, rail yards and the external stations representing highway traffic. Several separate steps are required to collect freight information for these specific spatial locations. These were detailed in Parts 2 and 3.

After taking imports and exports out of the transactions table, the attraction and production of shipments to and from all TAZs can be calculated using equations (1) and (2). At first, the technical coefficients were calculated from the transaction table. Employment data were disaggregated to the value of commodities at each TAZ The disaggregated value is denoted as the total output of a commodity in a TAZ given base year employment in a sector and the same TAZ. Then, the attraction or production is calculated by multiplying the technical coefficients matrix with the vector of the total output of commodity in a TAZ given base year employment in a sector and the same TAZ.

4.2. Attraction and production of freight trips in intraregional production in each TAZ

Two equations were used to calculate jobs associated with the attraction and production of freight at each TAZ. Equation (1) tallies the total commodity I required to support production in zone z:

$D^z_i = \Sigma_j a_{i,j} \cdot X^z_j$ + sector i shipments to zone z from transshipment zones (imports) and from other zones to accommodate local final demand not associated with households; (Equation **1.**)

where X^z_j = the total output of commodity j in zone z given base year employment in sector j and zone z, and

$a_{i,j}$ = is the i, jth element of **A**, the matrix of value demand coefficients for the (open) input-output model. This is the flow from i to j per unit output of j.

Similarly, the total supply of output j furnished by zone z is calculated in equation (2),

$O^z_j = \Sigma_i b_{i,j} \cdot X^z_i$ + sector j shipments to transshipment zones from zone z to accommodate nonlocal final demand (exports) and to other zones to accommodate local final demand not associated with households;

(Equation **2.**)

where X^z_i = the total output of commodity i in zone z given base year employment in sector i and zone z, and

$b_{i,j}$ = is the i, jth element of **B**, the matrix of value supply coefficients for the (open) input-output model. This is the flow from i to j per unit output of i.

Since the result is a long list for 1527 zones, only selected results are shown in Table 4.1. The summary of the total value and jobs is in Table 4.2.

Table 4.1 TRIP ATTRACTION PRODUCTION BASED ON EQUATIONS (1) AND (2)

($000s)

Zones	A1	P1	A2	P2	A3	P3	A4	P4	A5	P5	…
Zone 1	25.86	25.86	0.2	0.01	2.85	0	37.2	33.77	4.41	0.33	…
Zone 2	6.68	7.67	11.74	1.22	6.64	0.58	62.18	49.22	21.13	32.63	…
Zone 3	564.55	706.26	567.53	305.3	4210.35	240.18	7090.8	4986.41	4001.91	3783.37	…
………											
Zone 1525	722.62	734.65	819.73	426.12	12033.68	348.35	13261.05	4834.25	10562.51	7077.66	…
Zone 1526	8.64	16.11	3.38	4.52	20.18	6.47	94.97	67.77	39.77	76.84	…
Zone 1527	15.31	29.63	11.89	14.73	54.15	12.31	223.95	145.79	95.73	178.96	…
Total	1,351,904	1,923,742	2,483,899	757,335	11,205,735	673,931	20,723,609	15,679,041	15,758,764	15,553,332	…
$/job	137,268		134,590		37,914		133,556		107,726		…
A Job	10		18		296		155		146		…
P Job		14		6		18		117		144	…
A&P $	3,275,646		3,241,234		11,879,666		36,402,650		31,312,096		…
A&P Job	24		24		313		273		291		…

Source: Author calculation from equations (1) and (2), as well as CTPP employment data.

Notes: The dollar values of total attraction and production for each sector are converted to equivalent jobs by the corresponding $/job value from Table 3.18. A job is the equivalent job of attraction. P job is the equivalent job of production. A & P is the combination of attraction and production.

Table 4.2 SUMMARY OF TRIP ATTRACTION AND PRODUCTION, SCAG REGION

Total attraction and production value (K$)	Attraction jobs (1,000 jobs)	Production jobs (1,000 jobs)	Total attraction and production jobs (1,000 jobs)	Average of attraction and production jobs (1,000 jobs)
258,202,089	1,799	1,849	3,648	1,824

Source: Author calculation from table 4.1.

4.3. The tonnage and value of freight as well as jobs generated by freight at each site

The combination of tonnage and value of freight movement in and out of the SCAG region by sector and by mode are listed in Tables 8 and 9. The tables also include the calculation of jobs generated at each site. Because the seaports, airports, rail yards and highway entry points are located in specific traffic analysis zones, it is convenient to represented them on GIS-based map and integrated them with the other GIS-based data.

Table 4.3 FREIGHT ORIGIN AND DESTINATION BY SECTOR AND MODE, SCAG REGION

(Part I: Seaports)

		Imports					Exports					
Name	Sectors	Weight (KTons)	Value (M$)	To SCAG (M$)	$/Job	Job equiv. dest for SCAG	Weight (KTons)	Goods Value (M$)	From SCAG (M$)	$/Job	Job equiv. origin from SCAG	Import & export job equiv.
Seaport (1996)*1												
Long Beach (TAZ# 603)	Mining	24591	33,731	16,330	134,590	121,331	10,246	14,054	4,414	134,590	32,795	154,126
	Durable	9862	13,528	6,549	107,726	60,793	2,467	3,384	1,063	107,726	9,865	70,658
	Non-Dur	3440	4,719	2,284	133,556	17,104	7,400	10,151	3,188	133,556	23,869	40,973
	UnKnown	50	69	33			93	128	40			
Los Angeles (TAZ# 564)	Mining	13743	18,851	10,407	134,590	77,326	9,823	13,474	4,825	134,590	35,849	113,175
	Durable	9900	13,580	7,497	107,726	69,593	1,928	2,645	947	107,726	8,791	78,384
	Non-Dur	4206	5,769	3,185	133,556	23,848	5,441	7,463	2,673	133,556	20,011	43,859
	UnKnown	65	89	49			52	71	26			
Seaport Total	Mining	38,334	52,582	26,737	134,590	198,656	20,069	27,529	9,239	134,590	68,644	267,301
	Durable	19,762	27,107	14,046	107,726	130,386	4,395	6,029	2,010	107,726	18,656	149,042
	Non-Dur	7,646	10,488	5,469	133,556	40,953	12,841	17,614	5,860	133,556	43,880	84,832
	UnKnown	115	158	82			145	199	66			

(Part II: Airports)

Name	Sectors	Imports: Weight (KTons)	Imports: Value (M$)	Imports: To SCAG (M$)	Imports: $/Job	Imports: Job equiv. dest for SCAG	Exports: Weight (KTons)	Exports: Goods Value (M$)	Exports: From SCAG (M$)	Exports: $/Job	Exports: Job equiv. origin from SCAG	Import & export job equiv.
Airport (1996)*2												
Ontario	Durable	204	17,748	4,437	107,726	41,187	204	17,748	4,437	107,726	41,187	82,374
	Non-Dur	15	2,365	591	133,556	4,427	15	2,365	591	133,556	4,427	8,855
	Total	219	20,113	5,028		45,614	219	20,113	5,028		45,614	91,228
LAX	Durable	885	76,966	19,242	107,726	178,616	885	76,966	19,242	107,726	178,616	357,232
	Non-Dur	63	10,257	2,564	133,556	19,200	63	10,257	2,564	133,556	19,200	38,401
	Total	948	87,224	21,806		197,816	948	87,224	21,806		197,816	395,632
Burbank	Durable	13	1,173	293	107,726	2,722	13	1,173	293	107,726	2,722	5,444
	Non-Dur	1	156	39	133,556	293	1	156	39	133,556	293	585
	Total	14	1,329	332		3,015	14	1,329	332		3,015	6,029
Long Beach	Durable	19	1,662	415	107,726	3,856	19	1,662	415	107,726	3,856	7,712
	Non-Dur	1	221	55	133,556	415	1	221	55	133,556	415	829
	Total	20	1,883	471		4,271	20	1,883	471		4,271	8,541
John Wayne	Durable	2	195	49	107,726	454	2	195	49	107,726	454	907
	Non-Dur	0	26	7	133,556	49	0	26	7	133,556	49	98
	Total	2	222	55		502	2	222	55		502	1,005
Airport Total	Durable	1,124	97,744	24,436	107,726	226,835	1,124	97,744	24,436	107,726	226,835	453,669
	Non-Dur	80	13,026	3,257	133,556	24,384	80	13,026	3,257	133,556	24,384	48,767
	Total	1,204	110,770	27,693		251,218	1,204	110,770	27,693		251,218	502,436

(Part III: Rail)

Rail (ITMS, 1992) *3

		$/ton	Total In (kton)	Total In (M$)				Total out (kton)	Total out (M$)				
Rail Total	Mining	216.29	24,628	5,327				125	27				
	Durable	510.60	32,247	16,465				2,784	1,422				
	Non-Dur	571.53	62,463	35,700				25,038	14,310				
	Trans-Util	110.68	54,234	6,002				4,522	501				
			173,572					32,469					

Rail (SCAG, 1995) *5

		$/ton	SCAG dest (ktons)		M$	$/Job	Job equiv. dest for SCAG	SCAG origin (ktons)		M$	$/Job	Job equiv. origin from SCAG	Total (jobs)
Rail Total	Mining	216.29	13,536		2,928	134,590	21,754	159		34	134,590	255	22,009
	Durable	510.60	17,724		9,050	107,726	84,008	3,550		1,813	107,726	16,827	100,835
	Non-Dur	571.53	34,332		19,622	133,556	146,917	31,925		18,246	133,556	136,617	283,534
	Trans-Util	110.68	29,808		3,299	99,713	33,086	5,766		638	99,713	6,400	39,487
			95,400				285,765	41,400				160,100	445,865

(Part IV: Trucks)

Truck(ITMS, 1992) *4

		$/ton	Total In (ktons)	Total In (M$)				Total out (ktons)	Total out (M$)				
Truck Total	Mining	25.37	32,885	834				22,224	564				
	Durable	1410.49	27,456	38,726				31,358	44,231				
	Non-Dur	908.87	43,373	39,421				49,551	45,035				
	Trans-Util	384.36	22,921	8,810				32,896	12,644				
			126,635					136,029					

Truck (SCAG, 1995) *6

		$/ton	SCAG dest (ktons)		M$	$/Job	Job equiv. dest for SCAG	SCAG origin (ktons)		M$	$/Job	Job equiv. origin from SCAG	Total (jobs)
Truck Total	Mining	25.37	62,609		1,589	134,590	11,804	38,442		975	134,590	7,247	19,051
	Durable	1410.49	52,273		73,731	107,726	684,427	54,243		76,510	107,726	710,225	1,394,652
	Non-Dur	908.87	82,578		75,053	133,556	561,962	85,712		77,902	133,556	583,288	1,145,250
	Trans-Util	384.36	43,639		16,773	99,713	168,216	56,903		21,871	99,713	219,342	387,557
			241,100				1,426,408	235,300				1,520,102	2,946,511

Source:*1. Weight is based on Water Borne Commerce of the United States (1996), Total cargo value in 1996 is $80.1 billion (http://www.polb.com/cv.html), Cargo value as $ 1,372 per short ton based on author's calculation.

*2. LAX airport statistics report (http://www.lawa.org/lax/html/cargo.htm). Cargo value is $92,020 per ton based on author's calculation. The total is from airport facts, the durable and nondurable sectors are derived from Commodity Survey of U.S.

*3. ITMS freight rail data (1992). No information available for the proportions of origin and destination from and to SCAG region.

*4. ITMS highway data (1992). No information available for the proportions of origin and destination from and to SCAG region.

*5. SCAG inter-regional good movement study (1995). Sectors are scaled from ITMS freight rail data (1992). Dollar ton calculated from Commodity Flow Survey on U.S. and California.

*6. SCAG inter-regional good movement study (1995). Sectors are scaled from ITMS highway data (1992). Dollar ton calculated from Commodity Flow Survey on U.S. and California.

Table 4.4 FREIGHT IN AND OUT SCAG REGION BY SECTOR AND MODE

MODE	Sector	In (M$)	Out (M$)	In (ktons)	Out (ktons)	Job equiv. dest for SCAG	Job equiv. origin from SCAG
Seaport	Mining	26,737	9,239	19,488	6,734	198,656	68,644
	Durable	14,046	2,010	10,238	1,465	130,386	18,656
	Non-Dur	5,469	5,860	3,986	4,271	40,953	43,880
	UnKnown	82	66	60	48		
	Total	46,335	17,175	33,772	12,518	369,995	131,180
Airport	Durable	24,436	24,436	266	266	226,835	226,835
	Non-Dur	3,257	3,257	35	35	24,384	24,384
	Total	27,693	27,693	301	301	251,218	251,218
Rail	Mining	2,928	34	13,536	159	21,754	255
	Durable	9,050	1,813	17,724	3,550	84,008	16,827
	Non-Dur	19,622	18,246	34,332	31,925	146,917	136,617
	Trans-Util	3,299	638	29,808	5,766	33,086	6,400
	Total	34,898	20,731	95,400	41,400	285,765	160,100
Truck	Mining	1,589	975	62,609	38,442	11,804	7,247
	Durable	73,731	76,510	52,273	54,243	684,427	710,225
	Non-Dur	75,053	77,902	82,578	85,712	561,962	583,288
	Trans-Util	16,773	21,871	43,639	56,903	168,216	219,342
	Total	167,146	177,258	241,100	235,300	1,426,408	1,520,102
Total		276,072	242,856	370,573	289,519	2,333,386	2,062,601

Source: Author calculation from Table 4.3.

4.4. Discussion

CTPP employment data in 1990 report that the total employment in the SCAG region was about 6.61 million. Our calculation of total jobs associated with intraregional freight trip attractions is 1.799 million and the total jobs associated with intraregional freight trip productions is 1.849 million. By this approach, and averaging these two results, jobs associated with consumption internal to the SCAG region was 1.82 million.

Throughout previous sections, we have estimated various types of jobs for small geographic areas. Summing these estimates for the region, allows us to compare these to actual known control totals. The sum of the estimates, the "virtual" jobs generated at sea ports, airports, rail yards and highway entry zones was approximately 2.33 million for inbound and 2.06 million for outbound traffic.

By this approach, the total jobs in the SCAG region is 6.21 million (1.82 + 2.33 + 2.06 million)., which, considering the range of sources used in our calculations, is reasonably close to the total employment of 6.61 million reported by CTPP (Table 4.5).

Table 4.5 COMPARISON OF "VIRTUAL" JOBS AND REAL JOBS

(Millions of jobs)

"Virtual" jobs				Real Jobs
Jobs associated with intraregional freight trips	"Virtual" jobs for inbound traffic at external zones *1	"Virtual" jobs for outbound traffic at external zones *1	Total	
1.82	2.33	2.06	6.21	6.61

Source: Real jobs come from CTPP employment data (1990).
Jobs associated with intraregional freight trips come from Table 4.2.
"Virtual" jobs for inbound and outbound traffics at special sites come from Table 4.4.
Total is the sum of jobs associated with intraregional freight trips and "Virtual" jobs for inbound and outbound traffics at the external zones.

Notes: 1. External zones indicate seaports, airports, rail yards and highway entry points.

5. Network Analysis

Traditional transportation planning utilizes a well known four-step model. The major difference for the network analysis conducted in this study is that not only personal trips but also freight trips are modeled in an integrated modeling system. Another difference is that highway network analysis for freight movements usually does not require a mode choice analysis. Therefore, an adjusted three-step model was developed (Fig. 9), which includes trip generation, trip distribution and traffic assignment. Most of the required trip generation information was developed in the previous sections of this report.

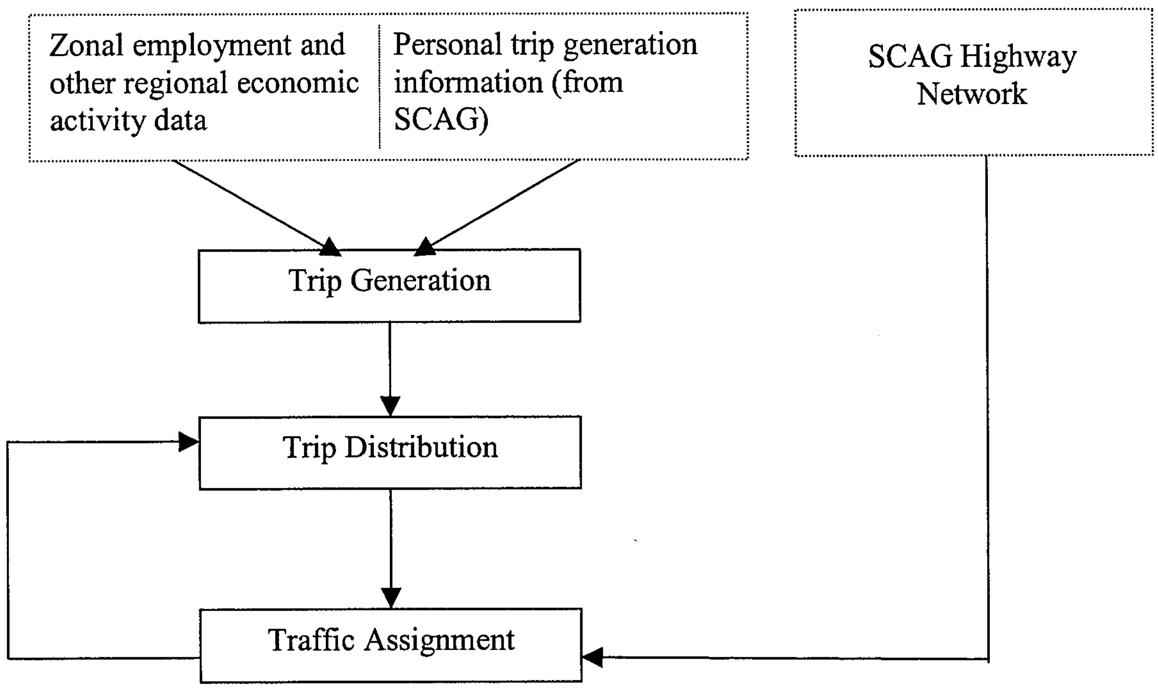

Figure 5.1 Three-step model for freight network analysis.

5.1. Trip Generation

(1) Freight Trip Generation

Freight shipments are normally divided into three categories: interregional freight, intraregional freight, and pass-through. Intraregional freight shipments are those whose origin and destination zones are both internal zones of the SCAG region. Interregional shipments are those with either origin or destination zones internal to the SCAG region. Pass-through freight trips are those with both origin and destination zones external to the SCAG region, but with some segments of the trip within the region.

Interregional together with pass-through shipments enter and leave the highway network from two seaports, five airports, two rail yards, and twelve highway entry points. These external zones are listed by mode as follows:

- Seaports (2)

Port of Long Beach and Port of Los Angeles

- Airports (5)

Ontario International Airport, Los Angeles International Airport (LAX), Burbank Glendale Pasadena Airport, Long Beach Airport, John Wayne Airport.

- Railway (3)

There are eight railway entry points at the boundaries of the SCAG region defined by ITMS (Fig. 7). Rail shipments, arriving and leaving were allocated to the three regional rail freight yards in the SCAG region.

There are actually five major rail facilities for freight movement: the Intermodal Container Transfer Facility (ICTF) in Long Beach, the LA Transportation Center at LA North Union Station (LA NUS), the Santa Fe Hobart Yard, the LA Intermodal Facility, and the Barstow Intermodal Facility in San Bernardino. Because the annual capacity of Barstow Intermodal Facility is much smaller than the capacity of the others, it is ignored. The Santa Fe Hobart Yard and the LA Intermodal Facility are located very close to each other and are combined into one facility in this study and represented as Hobart Yard Facility (HYF). Therefore, only three rail facilities are considered and treated similarly to the seaports and airports. They are: the Intermodal Container Transfer Facility (ICTF) in Long Beach, the LA Transportation Center at LA North Union Station (LA NUS), and the Santa Fe Hobart Yard joined with the LA Intermodal Facility (HYF).

ITMS reported the annual capacity of the three facilities as follows: ICTF 500,000 tons, LA NUS 300,000 tons, and HYF 750,000 tons. Because there are no annual freight movement data for these three facilities, the known annual capacities of the facilities were used as the regional proportions of rail freight movement allocated to the rail yards.

- Highway

The entry points of highway freight flows are designated by ITMS at twelve freeway entry points at the boundaries of the SCAG region. They are I-40 East, SR 62 East, SR 111 South, I-5 North, I-10 East, I-15 North, SR 86 Southeast, US 101 Northwest, US 395 North, I-5 South, I-15 South, SR 58 West (Fig. 8).

1) Intraregional freight trip generation

The calculation of intraregional freight trips is based on a transactions table developed from the RSRI regional-input output model (discussed in Section 4). The RSRI transactions table was aggregated to 17 sectors (Table 3.17). This transactions table was used with the CTPP employment data to calculate the attraction and production of seventeen commodities at each traffic analysis zone (Table 4.1). The summary of transactions across the sectors is shown in Table 5.1.

Table 5.1 SUMMARY OF COMMODITY TRIP ATTRACTIONS AND PRODUCTIONS, SCAG REGION, 1990

		Attraction		Production	
Index	Sectors	($000s)	(1000 jobs)	($000s)	(1000 jobs)
1	Agriculture	1,351,904	10	1,923,742	14
2	Mining	2,483,899	18	757,335	6
3	Construction	11,205,735	296	673,931	18
4	Manufacturing (Nondurable)	20,723,609	155	15,679,041	117
5	Manufacturing (Durable)	15,758,764	146	15,553,332	144
6	Transportation	3,436,945	41	2,761,781	33
7	Communications and Utilities	16,581,719	150	4,229,620	38
8	Wholesale Trade	6,977,809	69	6,661,492	66
9	Retail	5,872,006	109	10,838,099	202
10	F.I.R.E.	13,278,643	101	11,000,504	84
11	Business Services	12,813,509	325	3,713,159	94
12	Personal Services	898,852	31	1,400,705	49
13	Entertainment and Recreation	1,769,562	33	5,828,859	110
14	Health	511,059	10	4,340,053	87
15	Educational Services	79,065	2	868,645	23
16	Professional and Related	14,970,572	266	6,628,362	118
17	Government	1,826,729	34	34,803,050	646
	Total	130,540,380	1,799	127,661,709	1,849

Source: Author Calculation from Table 4.1.

Of these sectors, most freight flows are related to four industries, mining, durable manufacturing, non-durable (non-dur) manufacturing, transportation and utilities.

The commodity flows at seaports, airports, highways and railways are also aggregated into four sectors, mining, durable manufacturing, non-durable (non-dur) manufacturing, and trans-util, where trans-util is the combination of transportation and utilities sectors. To calculate the total tonnage across sectors, the dollar per ton values from the California CFS for these sectors (Table 3.16, Part 2) were utilized. Results for the transaction flows at the selected sectors are listed in Table 5.2. For purposes of aggregate analysis and comparisons with regional control totals, trip production and trip attraction totals are averaged.

Table 5.2 INTRAREGIONAL TRANSACTIONS OF SELECTED SECTORS, SCAG REGION, 1990

Sectors	Attraction			Production			Average		
	($Millions)	(1000 jobs)	(1000 tons)	($Millions)	(1000 jobs)	(1000 tons)	($Millions)	(1000 jobs)	(1000 tons)
Mining	2,484	18	92,345	757	6	28,156	1,621	12	60,251
Manufacturing (Non-Dur)	20,724	155	10,928	15,679	117	8,268	18,201	136	9,598
Manufacturing (Durable)	15,759	146	19,988	15,553	144	19,728	15,656	145	19,858
Trans-Util	20,019	191	53,711	6,991	71	18,758	13,505	131	36,234
Total	58,985	511	176,972	38,981	339	74,909	48,983	425	125,941

Source: Author Calculation from Table 5.1.
Note: 1. Sector trans-util was a combination of the Transportation sector and Communication & Utilities.
2. The values of tonnage were calculated by the use of dollar ton values in table 3.16 (Part 2. California).

For the purpose of trip distribution and trip assignment, the intraregional and interregional commodity flows for these sectors were converted to passenger car equivalent values (PCEs; see Table 5.3).

2) Interregional and pass-through freight trip generation

These shipments were summarized in Table 4.4. These were also converted into PCEs.

3) Aggregation of regional freight trips

To study regional freight movements systematically, all the sub-totals are aggregated and shown in an O-D matrix by sectors (Table 5.3). Because the O-D matrix for the freight flows at the zonal level required the linking of trip ends (trip distribution), this aggregate O-D matrix was also converted to PCE's (Table 5.11).

Table 5.3 AGGREGATED O-D MATRIX OF FREIGHT FLOWS TO AND FROM SCAG REGION

O/D			TO: SCAG region	TO: External Zones			
				Seaport	Airport	Railway	Highway
FROM: SCAG region		$Million	48,983	17,175	27,693	20,731	177,258
		1000ton	125,941	12,518	301	41,400	235,300
		1000job	425	131	251	160	1,520
FROM: External Zones	Seaport	$Million	46,335				
		1000ton	33,772				
		1000job	370				
	Airport	$Million	27,693				
		1000ton	301				
		1000job	251				
	Railway	$Million	34,898				
		1000ton	95,400				
		1000job	286				
	Highway	$Million	167,146				
		1000ton	241,100				
		1000job	1,426				
Total		$Million					567,911
		1000ton					786,032
		1000job					4,821

Source: Author calculation from Table 4.4. and Table 5.2.

4) Passenger Car Equivalent (PCE) Conversion

To obtain passenger car equivalents (PCEs) for regional freight trips, it was necessary to get the number of truck-trips and the relation between truck-trips and PCEs. There is no direct source for number of truck-trips. Caltrans, however, has conducted screenline traffic surveys in recent years and has collected data for the number of trucks by axles. The summary of Caltrans' survey of truck volumes in the SCAG region is shown in Table 5.4, which also lists the PCE values for various axle numbers, obtained from the Highway Capacity Manual (TRB 1994).

Table 5.4 SUMMARY OF TRUCK VOLUME BY NUMBER OF AXLES, SCAG REGION, 1996

		Axles Number			
	Total	2	3	4	5+
Vehicles/Day	6,951,601	3,130,063	696,990	280,995	2,843,553
%	100.00	45.03	10.03	4.04	40.91
PCE		1.5	1.5	3.0	3.0

Source: Author Calculation from Caltrans' Traffic Volumes On The California State Highway System (CSHS), 1996. (http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/)
PCE value by axle was obtained from Highway Capacity Manual (TRB 1994), and adjusted by Sungbin Cho (1999).

The proportions of trucks by axle number are thought to be reliable. The Truck Inventory and Use Survey - United States (1992) provided the truck axle configurations for selected sectors (Table 5.5).

Table 5.5 TRUCK AXLE ARRANGEMENT FOR SELECTED SECTORS

(1000 Vehicles)

Axles	Mining	Manufacturing	Trans-Util
2	173.0	648.4	757.6
3	19.1	31.4	78.9
4	8.8	36.2	96.5
5+	19.5	70.6	496.9
Total	220.4	786.6	1429.9
%	9.0	32.3	58.7

Source: Truck Inventory and Use Survey, United States (1992). (http://www.bts.gov/ntl/data/tct52.pdf)

After obtaining information about the proportions of trucks by axles and the truck axle allocations for selected sectors, it is possible to establish the proportions of truck volume by axle and by sector (Table 5.6). The sum values of the rows are the truck proportions by axle, which are shown in Table 5.4, and the sum values of column are the truck proportions by sector, which is listed in Table 5.5. X_{ij} in Table 5.6 is the unknown values of axle-by-sector proportions, determined by invoking additional assumptions.

Table 5.6 PROPORTION OF SELECTED COMMODITY SECTORS BY NUMBER OF AXLES

(percent)

Axle	Mining	Durable	Non-Dur	Trans-Util	%
2	x11	x12	x12	x14	45.03
3	x21	x22	x22	x24	10.03
4	x31	x32	x32	x34	4.04
5+	x41	x42	x42	x44	40.91
%	9.04	16.14	16.14	58.68	100.00

Source: From Table 5.4 and Table 5.5.
Note: The proportions for durable and non-dur are assumed to be the same value for the same axle number.

To obtain a solution, it was assumed that the column sum proportions applied to all axle-sizes. The results are shown in Table 5.7.

Table 5.7 PROPORTION OF SELECTED COMMODITY TRUCK SHIPMENTS BY NUMBER OF AXLES

(percent)

Axle	Mining	Durable	Non-Dur	Trans-Util	%
2	4.06	7.26	7.26	26.43	45.03
3	0.91	1.62	1.62	5.88	10.03
4	0.37	0.65	0.65	2.37	4.04
5+	3.70	6.61	6.61	24.00	40.91
%	9.04	16.14	16.14	58.68	100.00

Source: Author organization from Table 5.6.

Besides truck proportions by axle, Table 5.4 also provides the values of PCEs by axle. By multiplying this PCE value by truck proportions for corresponding axle type in Table 5.7, we obtained the PCE values by sector (Table 5.8). The calculated PCE values are very similar across the selected sectors.

Table 5.8 TRUCK PCE VALUES FOR SELECTED SECTORS

Sector	PCE
Mining	2.17430
Durable	2.17481
Non-Dur	2.17481
Trans-Util	2.17419
Average	2.17440

Source: Author calculation from Table 5.4 and Table 5.7.

The Truck Inventory and Use Survey (1992) for the United States and for California provided the values of truck proportion across sectors, Table 5.9 listed the truck proportions for the selected sectors.

Table 5.9 PROPORTION OF TRUCK USAGE IN SELECTED SECTORS, 1992

(percent)

Sector	California	U.S.
Mining	1.75	4.26
Durable	6.58	6.91
Non-Dur	6.58	6.91
Trans-Util	85.09	81.91

Source: Author calculation from Truck Inventory and User Survey – U.S. and California, Census of Transportation (1992).

The total number of vehicle in the SCAG region counted by Caltrans in 1996 (Caltrans' Traffic Volumes on CSHS) was 89,549,200 vehicles, in which truck count was 6,951,601 vehicles and non-truck count was 82,597,599 vehicles. The proportion of trucks was approximately 7.76 percent. This value is probably an overstatement of trips because the truck trip distances are usually much longer than non-truck trip distances. An adjustment is required. The corrected proportion of truck trips was calculated by Sungbin Cho (1999). His method arrives at a total of 1.06 percent and was determined as follows.

From the Inter-modal Transportation Management System (ITMS) in 1992, Cho calculated that the average truck trip distance in California is 59.82 miles. Cho referred to SCAG technical documentation and found the average non-truck trip distance is 7.64 miles. Then, the truck trip distance is 59.82/7.64 or 7.83 times the non-truck trip distance. Based on the assumption that the probability of a vehicle observed is linearly proportional to the trip length of the vehicle, the trucks are counted 7.83 times more frequently than non-truck vehicles. Adjusting the truck count by truck distance, Cho calculated that the real number of trucks was 6,951,601/ 7.83 or 887,816, and the total number of vehicles is (89,549,200 - 6,951,601 + 887,816) or 83,485,415. Therefore, the truck trip proportion is 887,816/83,485,415 or 1.06%.

An alternative approach (Attachment C) generates the slightly lower value of average truck trip distance as 51.84 miles. In what follows, the lower value is utilized. The truck trip distance is 51.84/7.64 or 6.782746 times the non-truck trip distance, the real number of trucks is 6,951,601/6.782746 or 1,024,895, the total number of vehicles is (89,549,200 - 6,951,601 + 1,024,895) or 83,622,494, and the truck trip proportion is 1,024,895/83,622,494 or 1.2256%.

The adjusted truck trip proportion is 1.2256%. The SCAG O/D survey in 1992 gave the number of non-truck trips per day, which is 34,032,386 trips/day. To calculate the number of truck trips per day, the following function is used:

Daily Truck Trips / Total Daily Vehicle Trips = 1.2256 %

Where, Total Daily Vehicle Trips = Daily Truck Trips + Daily Non-truck Trips,
and Daily Non-truck Trips = 34,032,386 truck trips/day.

Therefore, Daily Truck Trips in SCAG region are 422,276 truck trips/day.

Based on this volume of daily truck trips, the values of California truck proportions across sectors in Table 5.9 were used to calculate the truck trips per day by sector. The results of truck trips per day by sector were used with the PCE/truck values in Table 5.8 to calculate the PCE per days for the selected sectors. The truck trips by sector and PCE trips by sector are shown in Table 5.10.

Table 5.10 CONVERSION TO PCE TRIPS PER DAY

Sector	California (%)	Truck trips/day	PCE/Truck	PCE trips/day
Mining	1.75	7,389.83	2.17	16,068
Durable	6.58	27,785.76	2.17	60,429
Non-Dur	6.58	27,785.76	2.17	60,429
Trans-Util	85.09	359,314.65	2.17	781,219
Total	100.00	422,276.00	2.17	918,144

Source: Author calculation from Table 5.8 and Table 5.9. The total Truck Trips/Day is 422,276, which was calculated on the basis of the SCAG O/D survey (1992) and the adjusted truck trip proportion of 1.2256 %.

From Table 5.10, the total PCE trips per day is 918,144. This value was used to convert the O/D matrix of freight flows into truck trips measured by PCEs. Since the PCE values are almost identical across sectors (Table 5.8), it is appropriate to use the tonnage of freight by mode in Table 5.3 to calculate the truck trips by PCE. The results are shown in Table 5.11. In the same way, the PCE values of trip production and attraction at each TAZ were calculated.

Table 5.11 TRUCK TRIPS, SCAG REGION

(PCEs/ day)

O/D		SCAG	External Zones				Total
			Seaport	Airport	Railway	Highway	
SCAG		147,108	14,622	352	48,358	274,848	485,287
External Zones	Seaport	39,448					39,448
	Airport	352					352
	Railway	111,434					111,434
	Highway	281,623					281,623
	Total	579,964	14,622	352	48,358	274,848	918,144

Source: Author calculation from Table 5.3 and Table 5.10

(2) Personal Trip Generation

Personal trips were generated on the basis of the 1992 SCAG O/D survey which provides the number of personal trips by purpose. The trip purposes include home-to-work, work-to-home, home-to-shop, shop-to-home, home-to-other, other-to-home, and other-to-other, etc. The home-to-shop trips include home-to-other, other-to-shop and work-to-other trips.

Personal trips were converted to vehicle trips. The conversion was conducted by the use of the average vehicle occupancy by trip purpose, which is collected in SCAG O/D survey.

5.2. Trip Distribution

In the trip generation step, the personal trips and freight trips generated above are aggregated as a whole or distributed to TAZs or specific sites. The PCE values of freight trip production and attraction for each TAZ are represented as follows:

P^z_i = trip production of commodity sector i in origin zone z,
A^z_j = trip attraction of commodity sector j to destination zone z .

These trip production and trip estimated in the trip generation step as { P^z_i, A^z_j } had to be distributed to zonal pairs Qij.

There are standard methods available to conduct trip distribution for personal trips. A doubly-constrained gravity model was used in this study. In the gravity model, the key task is to calculate and calibrate the distance decay coefficients.

For personal trips, a distributed trip table is available from the SCAG O/D survey data set. The distance decay coefficients were calculated directly from this distributed trip table. However, the distance decay coefficients for freight trips are unknown to us. To make things more complex, personal trips and freight trips affect the computation of the each other's trip distribution.. The mutual influences of personal trips and freight trips need to be treated in a systematic way.

A feedback system was developed to compute and calibrate the distance decay for trip distributions including both personal trips and freight trips (Fig. 10).

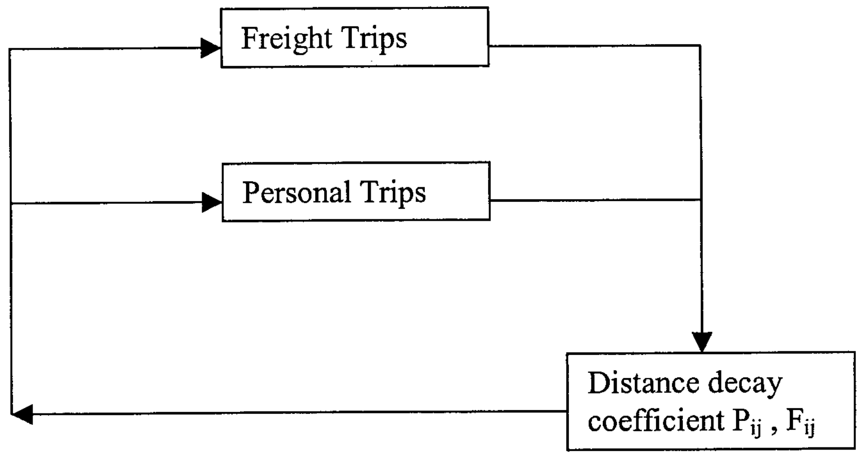

Figure 5.2 Calculation and Calibration of Trip Distribution

The initial distance decay coefficient values for personal trips (P_{ij}) are calculated from the distributed trip table obtained from the SCAG O/D survey data set. The initial distance decay coefficient values for freight trips (F_{ij}) are calculated in a way to minimize the difference between the observed and estimated trip productions. Then the distributions for personal trips and freight trips are calibrated by the use of selected delay functions. Because of the mutual influence of personal and freight trips, the calculation must iterate many times until the distance decay for these two kinds of trips reach stable values.

In this feedback system, the calibration and distribution of freight and personal trips follows two general steps. In the first step, stable values of freight distance decay coefficients were obtained after several iterations. The parameters in distance decay functions for personal trips are calibrated next. The calibrated results of personal trips change the inter-zonal traffic costs, which makes it necessary to calibrate the distance decay for freight trips again. In the feedback system, personal trips and freight trips are actually integrated as combined trips, making the distance decay for the two trips calibrated the same. In the second step, the calibrated combined trips are distributed on the basis of another gravity model.

Cho et. al. (1999) proposed a method based on the calibration criteria suggested by Putnam (1983). The distance decay for freight trips is calculated through a single-constrained gravity model. Putnam's criteria for the calibration of distance decay parameters are to minimize the difference between the estimated and observed trip productions, which are described as follows:

$$Minimize_{\beta_i} \mid \sum_o \{P_i^o(\beta_i) \bullet \ln(P_i^o)\} - \sum_o \{P_i^o(\beta_i) \bullet \ln(P_i^o(\beta_i))\} \mid \qquad \text{(Equation 3.)}$$

Where, $P^o_i(\beta_i)$ is the estimated trip production of commodity i in origin zone o,
and $P^o_i(\beta_i) = \sum_d A^d_i \bullet [B_i^o \bullet exp(-\beta_i \bullet c^{o,d}) / \sum_o B_i^o \bullet exp(-\beta_i \bullet c^{o,d})]$;
β_i is the distance decay coefficient for sector i;
$C^{o,d}$ is the travel cost from origin zone o to destination zone d;
P^o_i is the observed trip production of commodity i in origin zone o;
A^d_i is the trip attraction of commodity i to destination zone d;
B_i^o is the constant specific to sector i and origin zone o. It is equal to the square root of the total employment in the origin zone o.

The single-constrained gravity model is:

$$f(C^{o,d}) = \exp(\beta \bullet C^{o,d})$$

To conduct trip distribution of the combined trips, Cho et al. (1990) used a doubly-constrained gravity model as follows:

$$T_i^{o,d}(\beta) = P_i^o \bullet A_i^d \bullet [B_i^o \bullet H_i^d \bullet \beta_{0,i} \bullet \exp(-\beta_{1,i} \bullet C^{o,d}) \bullet C^{o,d(\beta_{2,i})}] \qquad \text{(Equation 4.)}$$

Where: $T_i^{o,d}(\beta)$ is the element of equilibrium trip interchange matrices associated with a given distance decay coefficient β.

$\beta_{0,i}$, $\beta_{1,i}$, and $\beta_{2,i}$ are elements in a vector of distance decay coefficients for sector i;

B_i^o is the constant specific to sector i and origin zone o. It is equal to

$$\sum A_i^d \bullet H_i^d \bullet \beta_{0,i} \bullet \exp(-\beta_{1,i} \bullet C^{o,d}) \bullet C^{o,d(\beta_{2,i})}]^{-1}, \text{ and}$$

H_i^d is the constant specific to sector i and origin zone d. It is equal to

$$\sum P_i^o \bullet B_i^o \bullet \beta_{0,i} \bullet \exp(-\beta_{1,i} \bullet C^{o,d}) \bullet C^{o,d(\beta_{2,i})}]^{-1}$$

$C^{o,d}$, P^o_i and A^d_i are the same as above.

The attraction P^z_i and production A^z_j of all PCEs, personal trips and freight trips, at each TAZ are now consistent with estimated flows between all zonal pairs, Q_{ij}.

5.3. Traffic Assignment

As the last phase in network analysis, traffic assignment models the trip-masker's choice of path between all available zonal pairs. Equilibrium-based travel demand models are usually adopted for the purpose of traffic assignment. For a congested network condition, strict network assignment models are appropriate to predict the equilibrium flows. Based on the theory of User-Optimal-Strict (UO-S)

On Network Assignment (NA), Sheffi (1985) provided a traffic assignment model that assumes perfect rationality among travelers, no temporal fluctuations and no modal or link interactions. Sheffi's method will be implemented to assign the passenger and truck trip volumes to the highway network of the SCAG region.

The optimization function to be used is:

$$MIN_{f_a} \sum_{a} \int_{0}^{f_a} C_a(x)dx \qquad \text{(Equation 5.)}$$

subject to $f_a = \sum_{r \in R} \delta_{ar} h_r \quad \forall a \in A$

$$\sum_{r \in R} h_r = D_{ij} \qquad \forall i \in I, j \in J$$

$$h_r \geq 0 \qquad \forall r \in R$$

where f_a is the total flow on arc a.

C_a is the average travel cost on arc a.

δ_{ar} is arc-path incidence variable; equal to one if arc *a* belongs to path *r*

h_r is flow on path *r*

r is a network path, and R is the set of all paths in *graph.*

Applying this algorithm to the minimization of the UO-S model requires a solution of all feasible values is generated at each step of iteration. When the results become convergent, the total travel time on the network is minimized, assigning all trips to the shortest travel-time path of the O-D pairs Q_{ij}.

A program to implement Sheffi's algorithm to the work at hand has been developed . However, the computing time for a large network, 1527*1527 TAZs of SCAG region, is quite long. Efficient programming is still to be done.

Another way to conduct traffic assignment is to use EMME/2 software. Though the traffic assignment functions in EMME/2 are based on similar algorithms, their computing time is far less than our own programs. The disadvantage of the EMME/2 program is the relative weakness of its graphic analysis, especially compared to GIS software. In future work, an integrated system will be developed to combine the graphic interface of the GIS platform and the functions of transportation modeling. Objective-oriented programming languages, like ESRI's Avenue or Microsoft's Visual C++ are the most appropriate tools for integrated modeling systems.

6. Implementation

We have shown that available data and methodologies are useful for the estimation and modeling of regional truck freight traffic. Metropolitan planning agencies are not limited to the choice of expensive freight origin-destination studies or the omission of freight flow data altogether. There is a third option, the use of secondary sources in the manner outlined in this report to estimate detailed fright flows. The data derived in this way are simply estimates but they are available at low cost. They can be loaded onto highway networks along with conventionally obtained passenger flow data to yield more accurate simulations and forecasts of network performance.

The integration of a regional input-output model, transportation modeling and geographic information systems allows a non-survey based tracing of the movement and impacts of freight flows over a large metropolitan area. After collecting, processing and manipulating freight data from various sources, a GIS-based origin-destination matrix has been built for Southern California freight flows. Through the comparison of total *estimated* jobs by sector and place ("virtual" jobs), those allocated to all of the origins and destinations (including the 1527 TAZs of the region, its seaports, airports, rail yards and highway entry points), and actual jobs reported by CTPP, the results of the freight matrix calculations are shown to be reasonable.

Beginning from a traditional four-step mechanism for transportation modeling, a revised three-step feedback model has been developed to create an origin-destination matrix that simultaneously accounts for all passenger and freight traffic. Tonnage-based freight data first are converted to PCE-based data in the trip generation steps. The personal trips and freight trips are distributed and calibrated together in the trip distribution step. A doubly-constrained gravity model is used in this task.

Since there is no need for mode choice, traffic assignment is the third and last phase of the model. A method of User-Optimal-Strict On Network Assignment (UO-S-NA) is proposed to assign all of the vehicle trips to the region's highway network.

Transportation modeling software like EMME/2 lacks a user-friendly interface and capability for database management. The methodologies and functionalities of GIS are adopted to counter this weakness of transportation models. At the same time, the strong network analyzing abilities of transportation models make GIS more powerful in special transportation applications. Though it is hard to conduct a full integration at the system level, some kinds of integration at functional levels, like data management, are feasible. The GIS-based freight matrix is an instance of this kind of integration. It is well suited for conducting further network analysis by transportation models or doing more data manipulation on a GIS platform.

Attachment A: SAS program to extract employment data from CTPP package 2.

```
option nocenter replace pagesize = 30000;

data ctppla;
  infile 'e:\P24480' linesize = 1804;
  input  countyw    8-10       placew    14-17      taztrw     34-39
         all        1634-1642  agr       1643-1651  min        1652-1660
         constru    1661-1669  man_nod   1670-1678  man_dur    1679-1687
         trans      1688-1696  comm      1697-1705  wholesal   1706-1714
         retail     1715-1723  fire      1724-1732  business   1733-1741
         personal   1742-1750  entert    1751-1759  health     1760-1768
         educate    1769-1777  other     1778-1786  pub_adm    1787-1795
         arms       1796-1804;

data _NULL_;
  set ctppla;
  file 'D:\Metrans\Ctpp\ctppla_p2.txt';
  put countyw placew taztrw all agr min constru man_nod man_dur trans comm wholesal
      retail fire business personal entert health educate other pub_adm arms;

run;
```

Attachment B: SAS program to aggregate SCAG employment data (4 digit, 1990).

```
libname dir 'D:\saswork\sicemp\';

/* Classify the variables we need in the original table */
data integr;
  set dir.Emp_1990;
  tract = ct90;
  agr      = sum (of SIC_000 - SIC_999);
  min      = sum (of SIC_1000 - SIC_1499);
  constru  = sum (of SIC_1500 - SIC_1799);
  man_nod  = sum (of SIC_2000 - SIC_2399 SIC_2600 - SIC_3199);
  man_dur  = sum (of SIC_2400 - SIC_2599 SIC_3200 - SIC_3999);
  trans    = sum (of SIC_4000 - SIC_4799);
  comm     = sum (of SIC_4800 - SIC_4999);
  wholesal = sum (of SIC_5000 - SIC_5199);
  retail   = sum (of SIC_5200 - SIC_5999);
  fire     = sum (of SIC_6000 - SIC_6799);
  business = sum (of SIC_7300 - SIC_7399 SIC_7500 - SIC_7699);
  personal = sum (of SIC_7200 - SIC_7299);
  entert   = sum (of SIC_7800 - SIC_7999 SIC_8400 - SIC_8499);
  health   = sum (of SIC_8000 - SIC_8099);
  educate  = sum (of SIC_8200 - SIC_8299);
  other    = sum (of SIC_7000 - SIC_7999 SIC_8100 - SIC_8199 SIC_8300 - SIC_8399 SIC_8600 - SIC_8999);
  pub_adm  = sum (of SIC_9100 - SIC_9799);

data _NULL_;
  set integr;
  file 'D:\Metrans\Ctpp\emp90.txt';
  put tract  agr min constru man_nod man_dur trans comm wholesal
      retail fire business personal entert health educate other pub_adm;

run;
```

Attachment C: Calculation of average truck trip distance in the SCAG region.

Cho (1999) used ITMS ton-miles to calculate average truck trip distance in the SCAG region. Table A.1 summarizes the data used for that calculation. The average truck trip distance in the SCAG region is equal to total ton-miles divided by total freight tonnage, which is 27441594/458749 or 59.82 miles.

Table A. 1 TONNAGE AND MILE SUMMARY, SCAG REGION

	Freight Tonnage (Tons)	Truck Trip Distance (Miles)	Tonnage-Miles
Internal-Internal	332196	7.64*1	2538688
Internal-External	108871	172.66*2	18797249
External-External	17682	345.31*3	6105657
Total	458749		27441594

Source: Author summary from Cho (1999).

Notes:
1. Internal-internal truck trip distance is assumed to be the same as average travel distance of automobiles, which is 7.64 in the SCAG region.
2. Internal-external truck trip distance is assumed to be a half of external-external truck trip distance.
3. External-external truck trip distance is calculated from the ITMS package.

A revised method was developed in this study. Cho (1999) used I-5 North, I-5 South, I-15 East and I-10 East to calculate truck trip distance. Since this study includes 12 highway entry points and these entry points are aggregated to six at the end, the calculation of truck trip distance requires to include not only I-5 North, I-5 South, I-15 East and I-10 East, but also I-15 South and US-101 Northwest.

Table A. 2 AVERAGE DISTANCE BETWEEN HIGHWAY ENTRY POINTS

(Miles)

Distance	I-5 S	I-5 N	I-10 E	I-15 N	I-15 S	US 101 NW
I-5 S		132.95	150.15	128.48	157.3	147.83
I-5 N	132.95		161.88	140.21	215.98	172.43
I-10 E	150.15	161.88		67.63	72.5	182.39
I-15 N	128.48	140.21	67.63		79.56	152.56
I-15 S	157.3	215.98	72.5	79.56		178.24
US 101 NW	147.83	172.43	182.39	152.56	178.24	

Source: Author calculation from ITMS package (1996).

Table A.2 lists the distance between selected entry points on the highways. Table 3 shows the tonnage ratios for the corresponding entry points in Table A.3. Table A.4 shows the results by multiplying distance values in Table A.2 with the corresponding tonnage ratio in Table A.3.

Table A. 3 TONNAGE PROPORTIONS FOR EXTERNAL-TO-EXTERNAL FREIGHT TRAFFIC BETWEEN HIGHWAY ENTRY POINTS

(percents)

Distance	I-5 S	I-5 N	I-10 E	I-15 N	I-15 S	US 101 NW
I-5 S	0.000000000	0.064872309	0.008088648	0.003509427	0.005006502	0.026867210
I-5 N	0.096571634	0.000000000	0.025376476	0.011010107	0.015706873	0.084290369
I-10 E	0.079105990	0.166714943	0.000000000	0.009018854	0.012866177	0.069045876
I-15 N	0.031732068	0.066874959	0.008338350	0.000000000	0.005161056	0.027696618
I-15 S	0.002719318	0.005730930	0.000714565	0.000310029	0.000000000	0.002373495
US 101 NW	0.046696223	0.098411739	0.012270535	0.005323824	0.007594897	0.000000000

Source: Author calculation from ITMS package (1996).

Table A. 4 MILE*TONNAGE PROPORTION FOR EXTERNAL-TO-EXTERNAL FREIGHT TRAFFIC BETWEEN HIGHWAY ENTRY POINTS

(miles)

Distance	I-5 S	I-5 N	I-10 E	I-15 N	I-15 S	US 101 NW
I-5 S	0	8.624773452	1.214510495	0.45089114	0.787522702	3.97177968
I-5 N	12.8391988	0	4.107943986	1.543727161	3.392370505	14.53418831
I-10 E	11.87776447	26.98781491	0	0.609945082	0.932797856	12.59327736
I-15 N	4.076936078	9.376538008	0.563922597	0	0.41061358	4.225396101
I-15 S	0.427748643	1.237766172	0.051805952	0.024665883	0	0.423051719
US 101 NW	6.903102585	16.96913612	2.238022815	0.812202655	1.35371451	0

Source: Author calculation from Table A.2 and Table A.3.

The summary miles of all items in table A.4 gives the revised average truck distance between external entry points, which is 153.56 miles. The external to external truck trip distance is assumed to be this value. The internal to external truck trip distance is assumed to be a half of this value or 76.78 miles. The internal to internal truck trip distance is assumed to be the same as average trip distance of automobiles or 7.64 miles. The average truck trip distance in SCAG region is calculated from Table A.5, which is equal to total tonnage miles divided by total freight tonnage: 38944989 / 786032 or 49.55 miles. If using the same pass-through value as Cho on the base of SCAG data source (1996), the average truck trip distance is 51.84 miles.

Table A. 5 REVISED TONNAGE AND MILE SUMMARY, SCAG REGION

	Freight Tonnage (Tons)	Truck Trip Distance (Miles)	Tonnage-Miles
Internal-Internal	309632	7.64*1	2366252
Internal-External	476400	76.78*2	36578737
External-External	0*4	153.56*3	0
Total	786032		38944989

Source: Author calculation from Table A.4.

Notes:
1. Internal-internal truck trip distance is assumed to be the same as average travel distance of automobiles, which is 7.64 in the SCAG region.
2. Internal-external truck trip distance is assumed to be half of external-external truck trip distance.
3. External-external truck trip distance is calculated from Table A.4.
4. The pass-through (external-to-external) for highway freight transport is omitted from Table A.5 because only one data source is available and it is impossible to do double checking. If using the same pass-through value as Cho on the base of SCAG data source (1996), the external to external freight tonnage is 17682 tons, the total freight tonnage is 803714 tons, and the total tonnage miles is 41660231 ton*miles. Then, the average truck trip distance is 41660231 / 803714 or 51.84 miles.

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