TRAVEL FORECASTING MODEL

Technical Memorandum

Prepared for:

Illinois Department of Transportation and
Indiana Department of Transportation

April, 2012

Table of Contents

Tables

Figures

1.0 Introduction

The Illiana Corridor was first envisioned in the 1900's as a vital link in an outer ring of highways encircling the Chicago region, and has since been studied in a number of forms over the last 40 years. Previous studies have indicated possible benefits from the development of an east-west transportation corridor extending from I-55 in Will County, Illinois to I-65 in Lake County, Indiana. These include providing an alternate route for motorists travelling the I-90/94 corridor, relieving traffic on the I-80 Borman/Kingery Expressway and U.S. 30, serving as a bypass for trucks around the congested metropolitan highways, providing access to one of the largest intermodal freight areas in the U.S. and the proposed South Suburban Airport, supporting area economic development, and the potential for substantial job creation. As traffic volumes on other highways in the region have increased, the associated congestion has resulted in travel delays with substantial economic impacts to industries that depend on the ability to efficiently move freight within and through the region.

The Illiana Corridor is described in the current 2040 long-range transportation plans of CMAP, NIRPC, and KATS. CMAP's GO TO 2040 Plan identifies the Illiana Corridor as an unfunded need and "supports initiating Phase 1 engineering for the project in order to narrow the scope to a few feasible alternatives, and recommends that these activities begin as a high priority." NIRPC's 2040 long-range transportation plan also included the Illiana Corridor as an unfunded need. The KATS adopted 2040 Long Range Transportation Plan (May 2010) includes the Illiana Corridor as a solution to the problem of through trucks using Kankakee County as a connection between Illinois and Indiana. In addition, the Illiana Corridor Tiered EIS is included in the Transportation Improvement Program (TIP) for CMAP and NIRPC.

In late 2006, the states of Indiana and Illinois, through their respective Departments of Transportation (DOTs), entered into a bi-state agreement that provided a framework for further development of the Illiana Corridor. This was followed in May 2007 by the passage of Senate Bill 105 in Indiana that enabled the Indiana Department of Transportation (INDOT) to perform a feasibility study that addressed the needs of the corridor, and identified financing options, alternative routes, and potential impacts. The *Illiana Expressway Feasibility Study* was completed in June 2009.

Following the Illiana Expressway Feasibility Study, the Illinois Department of Transportation (IDOT) initiated two additional studies; the Strategic Role of the Illiana Expressway (April 2010) and Illiana Expressway Economic Opportunities Analysis (April 2010). Both studies investigated the economic and social benefits that could result from the proposed expressway in the south and southwestern portions of the Chicago region.

On June 9, 2010, governors Pat Quinn of Illinois and Mitch Daniels of Indiana moved the Illiana Corridor project forward by signing a Memorandum of Agreement (MOA). This MOA outlined a mutual commitment to the project by both states.

Based on the previous feasibility studies, and given the particular location of the study area, special attention is given to long-distance trips, and especially to freight traffic. These previous feasibility studies have indicated strong through trip potential, with neither trip end within the northeast Illinois/northwest Indiana region. These trips need to be modeled with more attention than a typical urban area travel forecasting model would require, as they could have significant impact on the viability of a new facility. Secondly, freight is expected to be a major driver of traffic on a new facility. The Chicago region is a major hub for freight, including truck, rail, water and air commodity flows. Within the Illiana study area, several major intermodal freight facilities attract a large number of goods flows. Since truck traffic in particular is expected to benefit from a new facility in this area, an emphasis is put on truck flows for developing the travel forecasting model.

The base year for calibration and validation is 2010, as this is the most recent year for which traffic counts are available. The future year for analyses is 2040. A 2040 No Build (Baseline) scenario simulates traffic flows on the transportation system where all expected transportation improvements are implemented without any proposed build alternatives for the Illiana study area. Alternative scenarios for 2040 with different configurations of the build alternatives for the Illiana study area are analyzed and compared to the 2040 baseline scenario to evaluate the impacts of the new build alternatives on the regional and local transportation system.

The CMAP regional travel forecasting model was used as original starting point for development of the Illiana travel forecasting model. The CMAP model is used to the extent possible and was enhanced to better address the anticipated travel markets for this particular study.

2.0 Three-Tier Approach

The Illiana travel forecasting model is set up as a three-tier approach, providing a different level of detail in each tier that is most appropriate for every subtask. Figure 1 shows the three tiers.

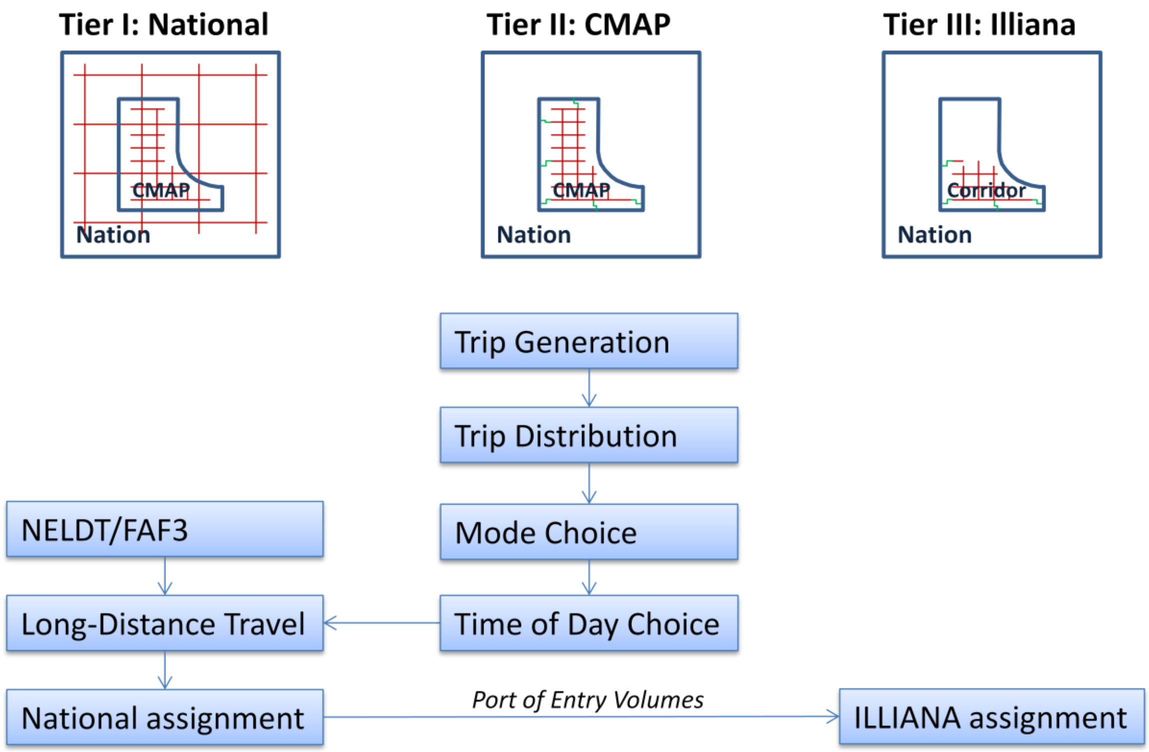


Figure 1: Three-Tier Approach for the Illiana Travel Forecasting Model

The model starts in Tier II with the CMAP regional travel forecasting model. The four steps of the CMAP model: trip generation (TG), trip distribution (TD), mode choice (MC) and time-of-day (TOD) trip stratification are run to simulate internal auto trips within the CMAP model area. The CMAP travel forecasting model represents decades of continuing development, so the Illiana Corridor Study wants to build upon this work and make the best use of available resources to model traffic flows. A local three-step truck trip model was developed to replace the existing CMAP truck trip table approach so as to better simulate truck trips within the CMAP area. The Illiana alternatives, however, are expected to carry significant external traffic, or trips that have at least one trip end outside of the CMAP study area. Since the CMAP model uses static trip tables for external trips, the Tier I modeling level of detail was added to the modeling stream. For a more detailed flow chart of the full modeling process including Tiers I, II and III see Appendix 1.

In Tier I, special attention is given to long-distance trips. For this layer, the CMAP zone system and network were merged with a national zone system and a national network. The national zone system is a customized input built from county and state geographies. The national network has as its starting point the FHWA's National Highway Planning Network[1] also customized for application with the Illiana study area. Using the national zone and network approach allows, for example, a trip from Pittsburgh to Minneapolis that is likely to travel through the northeast Illinois/northwest Indiana region, to be fully represented. Long-distance person trips are modeled by NELDT (National Estimate of Long-Distance Trips), and long-distance truck trips are based on commodity flows given by the Freight Analysis Framework 3.1 (FAF3). Tier I borrows auto trip tables from Tier II to account for local congestion when routing long-distance trips.

A subarea analysis is performed to extract trips for Tier III. This level represents the Illiana study area at a greater level of detail, while the northern part of the CMAP area is captured in a simplified way with a few zones only. Long-distance flows from the national level (Tier I) are fed into this layer as volumes at external stations.

The third tier is used to analyze Illiana alternatives that vary in detail, such as alignment changes and interchange locations. For major network changes, Tier I and Tier III will be run. Tier II is expected to be run initially for every model year, and is also expected to be run for different socioeconomic scenarios. Predicted 2040 accessibility changes from the travel forecasting model were used as input for the development of 2040 No Build and Build socioeconomic data inputs to the Tier II CMAP model. The trip tables generated by the Tier II model for Build socioeconomic scenarios will then be used in testing the Illiana build alternatives.

[1] National Highway Planning Network, 2011, http://www.fhwa.dot.gov/planning/nhpn/

3.0 Tier I: National Model

The national model at Tier I simulates long-distance trips. Both freight and auto trips are covered. Section 3.1 describes the methodology of the person long-distance model, and section 3.2 describes the truck long-distance model. Section 3.3 covers the traffic assignment methods used for the full set of trip tables (national and CMAP), and Section 3.4 outlines the calibration process.

3.1 Long-Distance Auto Trips

The Person Long-Distance Model (PLD) covers all trips that enter the CMAP area from somewhere else (External-Internal or E-I), leave the CMAP area (Internal-External or I-E) or travel through the CMAP area (External-External or E-E), as shown in Figure 2.

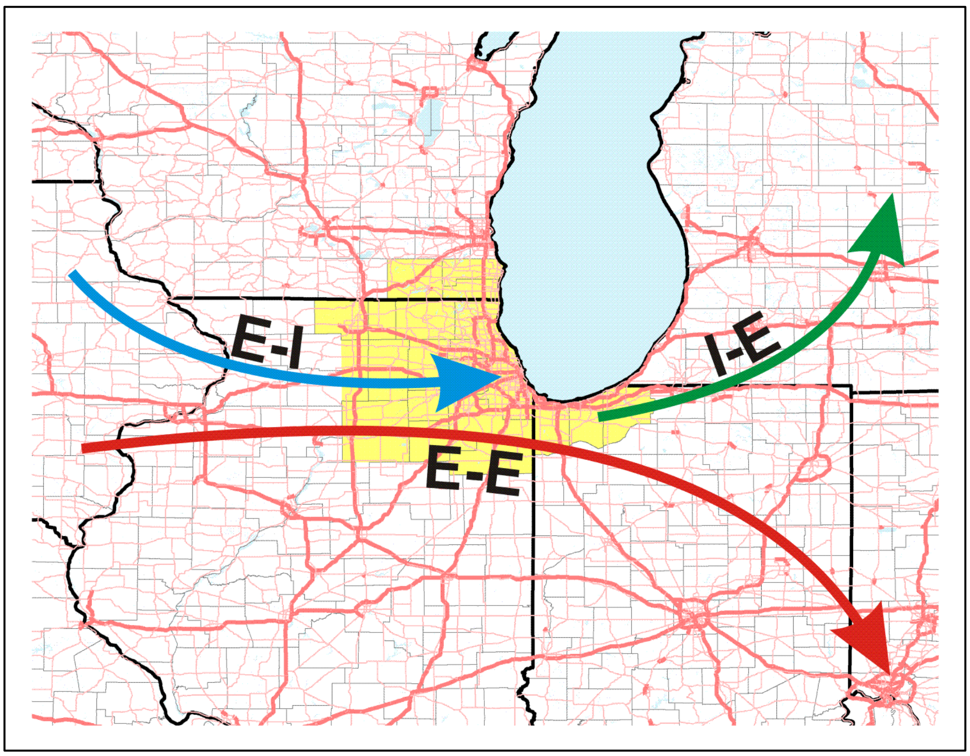


Figure 2: Long-Distance Trips Into (E-I), Out of (I-E) and Through (E-E) the CMAP area

3.1.1 Background

The simulation of long-distance travel is a relatively young field as most travel demand research has focused on urban travel demand. One of the most comprehensive approaches has been developed by Baik et al. (2008). Based on the 1995 American Travel Survey (ATS) they developed a four-step long-distance travel demand model for the air taxi, commercial airline and auto modes. It is unclear how well the four-step approach that has been developed for urban models applies to long-distance travel. Particularly, the second step - trip distribution- may be difficult to calibrate covering heterogeneous distances from 100 miles to 3,000 miles. Dargay et al. (2010) developed a long-distance travel demand model for Great Britain. Using a National Travel Survey from 2004-2006, they estimated demand for 5 different trip purposes by four modes for medium distances (50 to 150 miles) and long distances (> 150 miles). The elasticity for travel time and travel costs on travel demand by purpose, mode and distance were estimated. In scenarios, adjustments were made to rail fares, air fares, highway travel costs and fuel efficiency. The model is not geographically specific, as origin and destination are not provided. Trips are only divided into two distance classes, and overall demand is estimated. The methodology cannot be applied to estimate long-distance trips for Illiana.

Other projects explored the use of long-distance travel data. Haupt et al. (2004) developed a nationwide model for Germany for person travel and truck flows. Using data from navigation systems they were able to calibrate the model based on a large number of data records. Nevertheless, work trips were k-factored to match commuter trip tables provided by the federal employment agency. Finally, synthetic matrix estimation was used to tweak the trip tables to match traffic counts. This paper provides an interesting example of how the vast data availability from navigation systems can be exploited in travel demand modeling. However, the use of k-factors and synthetic matrix estimation limits the applicability of this model for policy analysis. Gur et al. (2009) analyzed the usability of cell-phone data in travel demand modeling in Israel. Though both cell-phone data and navigation-system data are impressive enrichments to travel patterns, they have yet to prove that they help modeling person travel. When using these data nothing is known on trip purpose, mode, vehicle occupancy or the socio-demographic characteristics of the traveler. These massive data are likely to be helpful in calibrating and validating travel demand models; however, their use in model estimation is limited so far.

3.1.2 Data

In 2001/2002, the Federal Highway Administration conducted the National Household Travel Survey (NHTS), which collected data on both daily and long-distance travel within the U.S. (FHWA 2010). The survey consisted of 69,817 telephone interviews conducted from March 2001 to May 2002. Respondents were asked about their daily travel patterns (short distance) as well as any travel within the past 28 days where the furthest destination was 50 miles or more away from their home (long distance). This data set offers a rich source of information for long distance trips by all modes of transportation within the U.S. A total of 45,165 (raw count) long distance data records are available, of which 1,688 cover Illinois residents and 1,136 cover Indiana residents. In 2010, FHWA published a new NHTS conducted in 2009 (FHWA 2010). This time, however, interviews focused on daily traffic only, without a special survey for long-distance travel. From this dataset, a total of 28,246 records (raw count) with trip length over 50 miles are available. An analysis of available data records shows that the smaller number of records and the different survey format makes these data unusable for long-distance travel in Illiana. While the NHTS 2002 asked people about their long-distance travel in the last 28 days, the NHTS 2009 asked about trips in a 24h period. As a consequence, long-distance travel is underrepresented in the NHTS 2009.

Table 1 summarizes the number of NHTS records for Illinois and Indiana. The two states combined make up more than 6 percent of all NHTS records. While the number of records is relatively small for travel demand modeling, this area is represented in the NHTS fairly well in comparison to other parts of the country.

Table 1: NHTS 2002 Records by Illinois and Indiana Origins and Destinations

		Destination			
		IL	IN	Other	Total
Origin	IL	816	162	710	1688
	IN	113	727	296	1136
	Other	526	236	41,579	42,341
	Total	1,455	1,125	42,585	45,165

Air travel data are published by the Bureau of Transportation Statistics based on ticketed passengers (BTS 2009). These data provide a ten percent sample of ticketed passengers between all U.S. airports, distinguishing between passengers changing flights and passengers having their final destination at one airport. Data are available by quarter, and to ensure compatibility with the NHTS data, air travel data were retrieved for 3/2001, 4/2001, 1/2002 and 2/2002.

Further data needs are employment and population data at the TAZ level within the CMAP area and at the county level outside of CMAP, as well as traffic counts for model validation.

3.1.3 Generate Missing NHTS Records

For privacy reasons, the NHTS dataset only reports the origin state for trips from states with a population of 2 million or more. Though this does not affect Illinois or Indiana directly, trips from smaller states such as the Dakotas or Nebraska are missing in the NHTS. For these smaller states, synthetic data records need to be generated based on travel data of surrounding states for which data are available. There are 15 states and Washington D.C. for which records need to be synthesized.

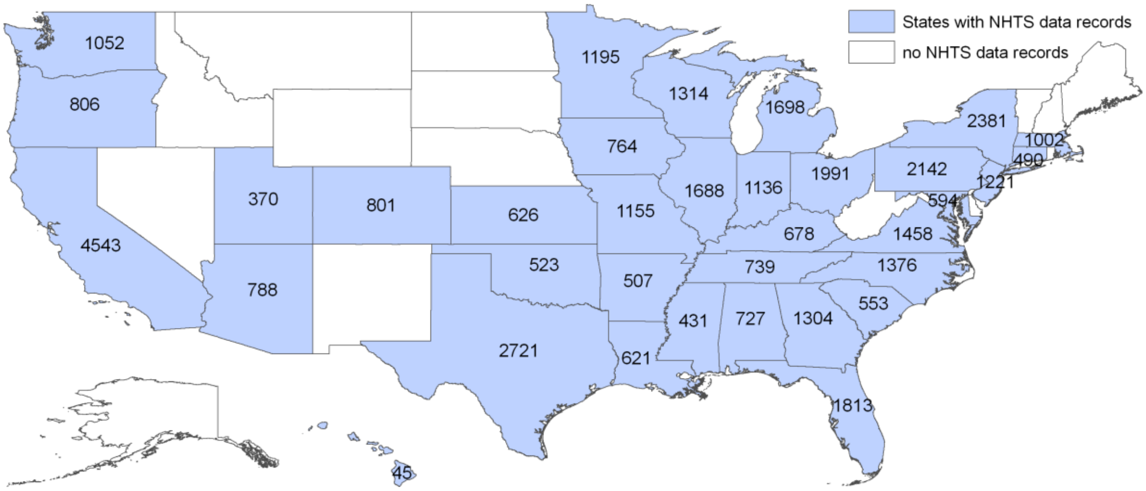


Figure 3 shows the number of data records with a long-distance trip by state. Most states without data records have neighboring states that can be used to synthesize missing data records. Maine records are generated based on Massachusetts datasets, and Montana records are generated based on Washington and Oregon data.

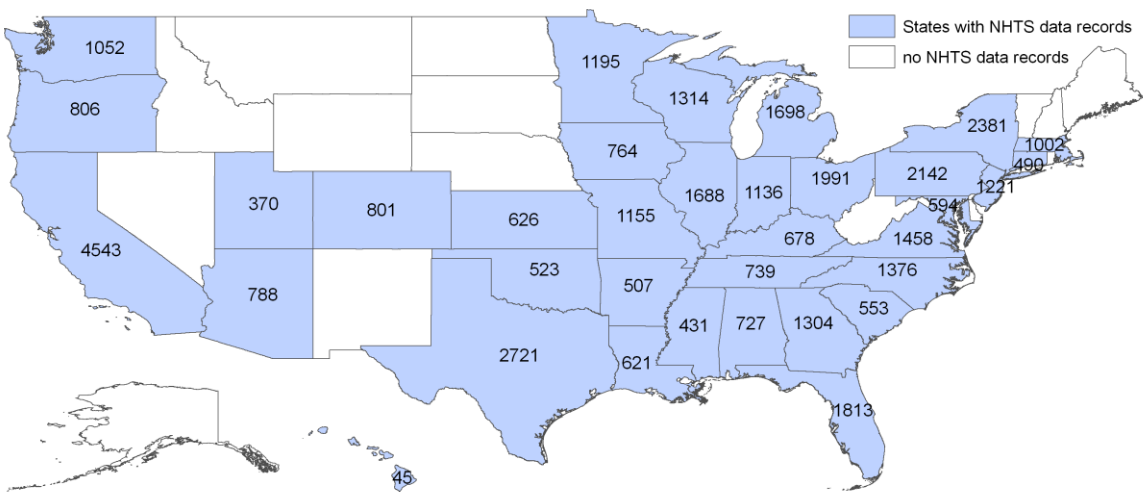


Figure 3: Number of NHTS Long-Distance Travel Data Records by Home State

To estimate the number of records that need to be synthesized for the 15 missing states and Washington D.C., a multiple regression analysis is done, where population serves as the independent variable. the intercept was forced to be 0 to ensure that if the population of a region is 0, the number of long-distance trips from that region is 0 as well. Table 2 summarizes the results of this multiple regression. A reasonable correlation was found for the modes auto, air and bus. The modes train, ship and other are sparsely available across the country and have a small sample sizes, it is little surprising that they show less correlation.

Table 2: Revised Estimation of NHTS Records per State

Auto	Estimate	Std. Error	t value	Pr(>|t|)	Air	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)					(Intercept)				
Population	1.23E-04	4.35E-06	28.29	<2e-16***	Population	1.14E-05	3.31E-07	34.47	<2e-16***
Adj. R-squared:	0.9581				Adj. R-squared:	0.9714			
N:	36790				N:	3110			
Bus	Estimate	Std. Error	t value	Pr(>|t|)	**Train**	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)					(Intercept)				
Population	2.89E-06	1.81E-07	15.96	<2e-16***	Population	1.53E-06	3.35E-07	4.56	6.34E-05***
Adj. R-squared:	0.8788				Adj. R-squared:	0.3612			
N:	833				N:	370			
Ship	Estimate	Std. Error	t value	Pr(>|t|)	**Other**	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)					(Intercept)				
Population	1.37E-07	2.82E-08	4.864	0.0000258***	Population	1.69E-07	7.24E-08	2.336	0.0255*
Adj. R-squared:	0.393				Adj. R-squared:	0.113			
N:	36				N:	70			
Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1									

These factors were used to estimate the number of trip records for states that were excluded from the NHTS survey as their population was below 2 million. A corresponding number of trip records were synthesized for these states, as shown in Table 3. Only auto, air and bus trips are analyzed subsequently as the modes train and ship are only available in selected areas and cannot be estimated with a general regression analysis.

Table 3: Number of NHTS Records to be Synthesized by State and Washington D.C.

State	Auto	Air	Bus
Alaska	79	7	2
Delaware	99	9	2
District of Columbia	70	7	2
Idaho	165	15	4
Maine	159	15	4
Montana	112	10	3
Nebraska	213	20	5
Nevada	267	25	6
New Hampshire	157	15	4
New Mexico	228	21	5
North Dakota	78	7	2
Rhode Island	132	12	3
South Dakota	94	9	2
Vermont	76	7	2
West Virginia	222	21	5
Wyoming	61	6	1

For each state listed in Table 3, up to four neighboring states were chosen. From these neighboring states, NHTS records were selected randomly to synthesize records for each state of Table 3. The destination of each synthesized record is set to ensure that the share of intrastate trips is the same as the average share of intrastate trips in neighboring states. This way, the characteristics of the travelers of neighboring states is copied, while the average trip length of neighboring states is approximately achieved.

Table 4 shows the synthesizing of auto long-distance travel records for New Mexico as an example. First, the number of intra-state, to-neighboring-states and other-destination travel records are summarized for the four neighboring states AZ, CO, OK and TX, resulting in an average of 84% of travelers who stay in the same state, 10% who visit neighboring states and 6% who travel further away. A corresponding number of records are chosen for New Mexico from the four neighboring states. After selecting a record, the origin is replaced with New Mexico, and the destination is replaced with NM for intra-state trips, with AZ, CO, OK or TX for trips to neighboring states, and for trips to other destinations the destination is given by the selected record. The same procedure is applied to all 15 states and Washington D.C., for which NHTS records are not published.

Table 4: Process to Synthesize Auto Long-Distance Travel Records for New Mexico

State	Intra-state	Neighboring state	Other destination
AZ	543	82	42
CO	605	55	50
OK	340	128	20
TX	2,110	159	130
Sum	3,598	424	242
Share	0.844	0.099	0.057
Total # of records NM	228 records for auto trips		
Records NM by mode	192	23	13
Choose destination from	NM	AZ, CO, OK, TX	given by sampled states

Alaska is particularly difficult as it has no neighboring US states, and – given its size – it has a very unique long-distance travel pattern. As an interim solution, Washington State was chosen as a “neighboring” state to Alaska. Though distances are big in Alaska, the absolute number of long-distance travelers is very small, and they rarely reach the Illiana corridor.

Because the NHTS is a national survey that interviewed long-distance travelers in their home state, no international visitors are included in the NHTS data set. International travelers need to be synthesized based on air travel data and land-border crossings from Canada and Mexico. Their characteristics are assumed to be comparable to American long distance travelers.

3.1.4 Nationwide Number of Long-Distance Travelers

As the NHTS data set is a sample of long distance travel, not all long distance trips of the entire population are included. Even though the NHTS data set includes weights for every data record, simply expanding the records based on these weights is not recommended (FHWA 2005: 5-7). Long-distance travel is an event that is too rare to expand from single records. If, for instance, a person reported two trips in a 28-day period, expanding this trip to:

2 trips / 28 days x 365 days = 26 trips per year

cannot be carried out with statistical confidence. This person may have done far fewer trips greater than 50 miles in this year. Because long distance trips are relatively rare, a simple expansion produces statistically insignificant results. Instead, the total number of air travelers provided by BTS air travel data is used to expand the NHTS nationwide.

Table 5: Expanded Number of Long-Distance Travelers in the U.S.

	Auto	Air	Bus	Train	Ship	Other
NHTS Records	36,790	3,110	833	370	36	70
Synthesized records	5,687	233	102			
Total number of records	42,477	3,343	935	370	36	70
BTS air statistics		84,640,725				
Expansion factor	25318.793					
Number of yearly travelers	1,075,466,370	84,640,725	23,673,071	9,367,953	911,477	1,772,316
Number of daily travelers	2,946,483	231,892	64,858	25,666	2,497	4,856

Table 5 shows the expanded number of long-distance travelers on an average day in the U.S. After synthesizing NHTS records for missing states (Table 3), a total of 3,343 air travel records is available. This only includes clean records that have all necessary data items. Given the number of air passengers according to BTS database, an expansion factor of 25,318.793 was calculated, which led to a yearly number of travelers for all modes.

The assumption behind this expansion is that the NHTS is a representative sample across all modes. If the share of auto and air records in the NHTS represents the mode split in reality, air travel data may be used to expand the NHTS data. Next, the yearly number was converted into daily travelers by dividing by 365. In urban travel demand models, it is common to use a smaller number than 365 to convert yearly in daily traffic volumes, as it is assumed that weekday traffic carries more trips than weekend traffic. For long-distance travel, however, weekends carry at least a similar number of trips as weekdays, particularly for personal trips. For lack of better information -the NHTS records do not report the weekday- yearly data was divided by 365 to derive travel on an average day.

It should be noted that Table 5 shows how many long-distance trips are started on a given day. Each record, however, describes a journey including both the outbound trip and the return trip. In the expansion process, NHTS records are duplicated until the number of air trips matches the observed total of 231,892 trips.

3.1.5 Direction of Travel

The NHTS data records describe tours, including outbound trip, possibly staying overnight at the destination, and return trip. For each long-distance traveler, the number of nights stayed away from home is provided by NHTS. As an average day shall be simulated, both the outbound and the inbound trip need to be represented. If someone is staying away from home for 0 nights, it is assumed that this person has the outbound trip and the return trip on the same day, thus the trip of this person is added to the trip table twice, from home state to destination state and from destination state to home state. Travelers that stay one night are assigned with half a trip from their home state to the destination state and another half trip from the destination state to the home state. For a two-night trip, one third of an outbound trip and one third of a return trip is added for the simulation of an average day, and so on.

$$\boldsymbol{trips_{state_a,state_b} = longtrips_{state_a,state_b} \cdot \frac{1}{nights+1}} \quad (1)$$

where $trips_{state_a,state_b}$ is the number of average daily trips from $state_a$ to $state_b$

$longtrips_{state_a,state_b}$ is the number of all trips from NHTS origin to NHTS destination

$nights$ is the number of nights away from home

In addition, the number of trips is influenced by the distance traveled, at least for auto trips. Someone traveling from San Francisco to Chicago has to drive approximately a day and half. Even if there were several drivers allowing the vehicle to travel without overnight stays, traffic would be overestimated if the entire trip from San Francisco to Chicago was assigned to the network as traveled on the one day simulated. The assumption was made that the average traveler would drive for a maximum of 750 miles per day, and then rest for an overnight stay. Trips below 750 miles are not adjusted, but trips longer than this threshold are reduced proportionally to the distance traveled.

$$trips_{state_a,state_b} = longtrips_{state_a,state_b} \cdot \frac{\sigma}{\max(\sigma, dist_{state_a,state_b})} \quad (2)$$

where $trips_{state_a,state_b}$ is the number of average daily trips from $state_a$ to $state_b$

$longtrips_{state_a,state_b}$ is the number of all trips from NHTS origin to NHTS destination

σ is a threshold the average traveler is assumed to be able to travel per day, for auto travel it is set to 750 miles

$dist_{state_a,state_b}$ is the travel distance from $state_a$ to $state_b$

This way, long-distance trips of more than 750 miles are scaled down to account for the fact that it is impossible to drive from coast to coast in a single day. A trip from San Francisco to Chicago (2,133 miles) would be assigned as 0.35 trips.

Finally, long-distance travel journeys need to be converted into trips. A journey from *i* to *j* is converted into an outbound trip from *i* to *j* and a return trip from *j* to *i*, assuming that each trip was a single-destination, single-purpose and single-mode trip.

3.1.6 Disaggregation

The NHTS reports trip origins and destinations by state. The simulation of travel demand on Illiana requires a geography much smaller than states, at least in the Midwest of the U.S. To make these long distance trips usable for Illiana, trip origins and destinations are disaggregated to the zonal level within the CMAP region and to the county level everywhere else. This disaggregation is done based on population and employment. Zones with more population and employment are expected to generate and to attract more long-distance trips than less populated counties. Furthermore, the larger the distance between two zones, the smaller is the attraction between them. This reasoning follows common gravity theory. The following equation is applied to disaggregate trips between states to trips between counties and zones:

$$tripsDisagg_{taz_i,taz_j} = trips_{state_a,state_b} \cdot \frac{weight_{taz_i,taz_j}}{\sum_{taz_k \in State_a} \left(\sum_{taz_l \in State_b} weight_{taz_k,taz_l} \right)} \qquad (3)$$

where taz_i is located in $state_a$
taz_j is located in $state_b$
taz_k are all zones located in $state_a$
taz_l are all zones located in $state_b$

The weights for disaggregation are calculated by:

$$weight_{taz_i,taz_j} = (\alpha_1 \cdot pop_i + \alpha_2 \cdot retEmp_i + \alpha_3 \cdot emp_i) \cdot (\beta_1 \cdot pop_j + \beta_2 \cdot retEmp_j + \beta_3 \cdot emp_j) \cdot \exp(\gamma \cdot d_{i,j}) \qquad (4)$$

where pop_i is population in zone *i*
$retEmp_i$ is retail employment in zone *i*
emp_i is total employment in zone *i*
$d_{i,j}$ is the travel distance from county *i* to county *j*

Alpha and beta are parameters to weight the impact on trip production and trip attraction of population and employment. **Table** 6 shows how these parameters are set differently for every trip purpose to weight production and attraction factors. With the exception of β_2, which was based on NHTS data, all values were asserted and should be subject to careful reevaluation if additional data become available.

The parameter γ was calibrated to match the average trip length of long-distance trips, which was calibrated separately for each of the 50 states and Washington D.C.

The result of this module is a trip table with daily trips between all CMAP zones and counties elsewhere. This trip table may be split into time-of-day periods and be assigned to the highway network.

Table 6: Parameters for Trip Production and Attraction

Parameter		Value	Reasoning
Business	α_1	0.5	A business trip starting in the morning is likely to start from the home location
	α_2	0.0	Retail is not expected to generate more long-distance trips than other industries
	α_3	0.5	A business trip starting later in the day is likely to start from the work location
	β_1	0.1	Only few business trips end at a household location (such as sales call)
	β_2	0.1	Retail facilities are expected to attract slightly more business trips than other industries
	β_3	0.8	Most business trips are attracted by other employment
Commute	α_1	1.0	All commute trips are assumed to start in a home location
	α_2	0.0	No commute trips start at a retail facility
	α_3	0.0	No commute trips start at employment locations
	β_1	0.0	No commute trips are attracted by households
	β_2	0.0	Retail facilities do not attract more long-distance commute trips than other employment
	β_3	1.0	All long-distance commute trips are attracted by employment
Personal	α_1	0.7	The majority of personal long-distance trips starts at home
	α_2	0.1	A few travelers stop at retail facilities before going on a long-distance trip
	α_3	0.2	A few people start personal long-distance trips after work from the work location
	β_1	0.5	Population is a major attractor of personal trips (value based on NHTS share of personal trips that visit friends or relatives)
	β_2	0.2	Some personal long-distance trips visit retail employment
	β_3	0.3	Some personal long-distance trips end at employment (particularly at hotels)

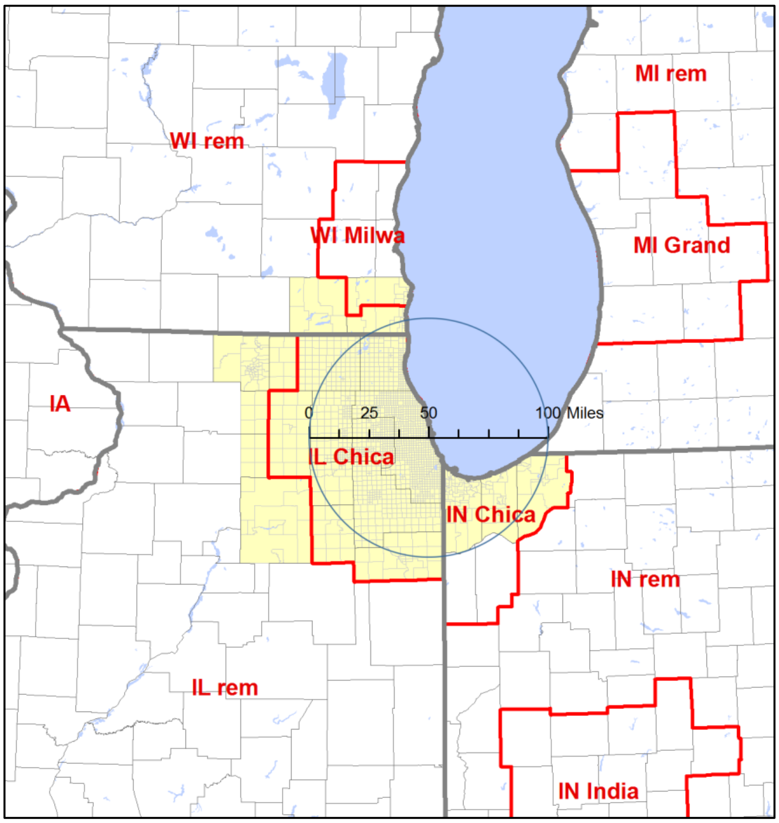
3.2 Long-Distance Freight Flows

Long-distance truck trips are generated from commodity flow data provided by the Federal Highway Administration of the U.S. Department of Transportation (Federal Highway Administration 2008) in the Freight Analysis Framework (FAF). The simulated truck trips cover North America to account for all relevant trucks trips of 50 miles or more. Trips that are internal to CMAP are included as long as they have a distance of 50 miles or more. Other internal truck trips with a shorter distance are covered by the local truck model, described in section 4.2.

3.2.1 Data

The third generation of the FAF data, called FAF^3, was released in summer 2010 and contains flows between 123 domestic FAF regions and 8 international FAF regions. Figure 4 shows the CMAP model area in yellow and the zones used by the FAF in red, including a 50-mile-radius circle around downtown Chicago.

Figure 4: CMAP Model Area and FAF Zones



FAF^3 data provide commodity flows in tons and dollars by:

- FAF zones (123 domestic + 8 international zones)
- Mode (7 types)
- Standard Classification of Transported Goods (SCTG) commodity (43 types)
- Port of entry/exit for international flows (i.e. border crossing, seaport or airport)

The base year is 2007, and freight flow forecasts are provided for the years 2015 to 2040 in five-year increments.

The FAF data contain different modes and mode combinations. For this project, the modes of Truck, Rail, Water and Air were analyzed. Even though truck is the main mode of interest for the Illiana Corridor Study travel forecasting model, the other three modes were included, as goods are commonly reloaded on trucks at modal transfer stations for delivery to their final destination. The remaining modes that are included in the FAF, namely "Multiple modes & mail", "Other and unknown" and "Pipeline", were not included in this study. Multiple modes as well as other and unknown provide insufficient information to be included, and goods shipped by pipeline commonly travel from the origin (such as a refinery) the destination (such as a gas station) without being reloaded on trucks. Omitting these three modes resulted in a loss of 13.6 percent of commodity flows in tons. Though this is a notable share, only a very small amount of these goods will ever be transported on the highway network, and therefore, omitting these flows is unlikely to affect truck travel for the Illiana Corridor Study.

As the CMAP region is a major hub for freight transportation, distribution centers and intermodal transfer stations are represented in the freight model. Distribution centers and intermodal transfer stations were included with these attributes:

- Location (as CMAP zone number)
- Modes served (trucks, rail, water or air)
- Size of facility

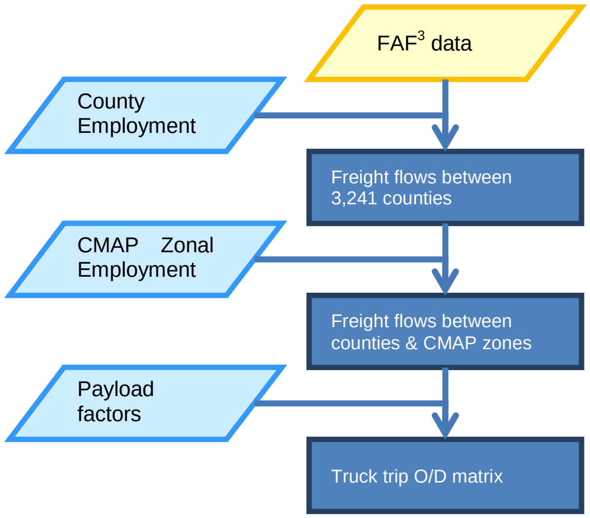
Further data required for the truck model include the Vehicle Inventory and Use Survey (VIUS) that was done for the last time in 2002. The U.S. Census Bureau publishes the data with survey records of trucks and their usage[2]. Finally, population and employment data are used for FAF3 data disaggregation, and truck counts are used to validate the model.

3.2.2 Truck Model Design

The resolution of the FAF data with 123 zones within the U.S. is too coarse to analyze freight flows for the Illiana Corridor Study. A method has been developed to disaggregate freight flows from FAF zones to counties and further to CMAP zones. An overview of the truck model design is illustrated in Figure 5. First, the FAF[3] data are disaggregated to counties across the entire U.S. using total employment in each county. Within the CMAP region, more detailed employment is used to further disaggregate to zones. Finally, commodity flows in tons are converted into truck trips using average payload factors.

2 http://www.census.gov/svsd/www/vius/products.html

Figure 5: Model Design of the Regional Truck Model

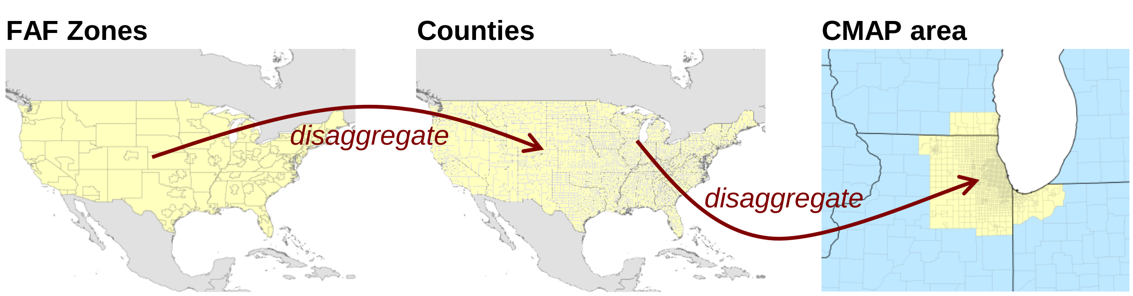


Output of this module is a truck trip table from all national zones to all nationalzones for two truck types, single-unit trucks and multi-unit trucks.

3.2.3 Commodity Flow Disaggregation

Freight flows are given by FAF zones. For some states, such as New Mexico, Mississippi or Idaho, a single FAF region covers the entire state. Flows from and to these large states would appear as if everything was produced and consumed in one location in the state's center (or the polygon's centroid). To achieve a finer spatial resolution, truck trips are disaggregated from flows between FAF zones to flows between counties based on employment distributions (Figure 6). Subsequently, trips are further disaggregated to TAZ in the CMAP model area.

Figure 6: Disaggregation and Aggregation of Freight Flows



In the first disaggregation step from FAF zones to counties uses employment by county in eleven categories:

Categories for disaggregation from FAF zones to counties

- Agriculture

- Construction Natural Resources and Mining
- Manufacturing
- Trade Transportation and Utilities
- Information
- Financial Activities
- Professional and Business Services
- Education and Health Services
- Leisure and Hospitality
- Other Services
- Government

County-level employment for agriculture was collected from the U.S. Department of Agriculture[3]. For all other employment categories, data were retrieved from the U.S. Bureau of Labor Statistics[4].

At the more detailed level of Illiana TAZ, less employment categories are available. The CMAP model works with two employment categories, namely retail employment and total employment. While these employment categories may be sufficient for the person travel demand model, a truck model requires more detail to ensure that trucks are generated in and attracted by the right zones. Using Dun & Bradstreet employment data, these two categories were further disaggregated into the following four categories:

Categories for disaggregation from counties to Illiana TAZ

- Agriculture
- Manufacturing
- Retail
- Office

These employment types serve to ensure that certain commodities are only produced or consumed by the appropriate employment types. For example, SCTG25 (logs and other wood in the rough) is produced in those zones that have forestry employment (the model uses agricultural employment as a proxy for forestry); this commodity is shipped to those zones that have employment in industries consuming this commodity, particularly manufacturing and construction.

The following equation shows the calculation to disaggregate from FAF zones to counties. A flow of commodity c from FAF zone a to FAF zone b is split into flows from county i (which is located in FAF zone a) to county j (which is located in FAF zone b) by:

3 http://www.nass.usda.gov/Statistics_by_Subject/index.php
4 ftp://ftp.bls.gov/pub/special.requests/cew/2010/county_high_level/

$$flow_{i,j,com} = flow_{FAF_a,FAF_b} \cdot \frac{weight_{i,com} \cdot weight_{j,com}}{\sum_{M \in FAF_a} \sum_{N \in FAF_b} weight_{m,com} \cdot weight_{n,com}} \tag{5}$$

where $flow_{i,j,com}$ = flow of commodity *com* from county *i* to county *j*

$county_i$ = located in FAF_a

$county_j$ = located in FAF_b

$county_m$ = all counties located in FAF_a

$county_n$ = all counties located in FAF_b

To disaggregate flows from FAF zones to counties, employment in the eleven categories shown above and make/use coefficients are used. The make/use coefficients were derived from input/output coefficients provided by the Bureau of Economic Analysis. These weights are commodity-specific. They are calculated by:

Production

$$weight_{i,com} = \sum_{ind} \left(empl_{i,ind} \cdot mc_{ind,com} \right) \tag{6}$$

Consumption

$$weight_{j,com} = \sum_{ind} \left(empl_{j,ind} \cdot uc_{ind,com} \right) \tag{7}$$

where $emp_{i,ind}$ = the employment in zone *i* in industry *ind*

$mc_{ind,com}$ = make coefficient describing how many goods of commodity *com* are produced by industry *ind*

$uc_{ind,com}$ = use coefficient describing how many goods of commodity *com* are consumed by industry *ind*

Table 7 shows the make coefficients applied. Many cells in this table are set to 0, as most commodities are produced by a few industries only. No value was available for commodities SCTG09 (tobacco products) and SCTG15 (coal). They were assumed to be produced by agricultural employment and mining, respectively. As only the relative importance of each industry for a single commodity is required, it is irrelevant to which value the entry for these two commodities is set, as long as the industry that produces this commodity is set to a value greater than 0 and all other industries are set to 0.

Table 8 shows this reference in the opposite direction, indicating which industry consumes which commodities.

Table 7: Make Coefficients by Industry and Commodity

Industry	Agriculture	Construction	Health	Leisure	Manufacturing	Mining	Retail	Wholesale	Service
SCTG01	811.6238	0	0	0	0	0	0	0	0
SCTG02	198.234	0	0	0	0	0	0	0	0
SCTG03	3669.689	0	0	0	0	324.679	0	0	0
SCTG04	159.456	0	0	0	114.4688	0	0	0	0
SCTG05	0	0	0	0	786.7564	220.2534	0	0	0
SCTG06	0	0	0	0	1289.469	0	0	0	0
SCTG07	205.8607	0	0	0	6551.506	0	0	0	0
SCTG08	0	0	0	0	1150.509	0	0	0	0
SCTG09	1	0	0	0	0	0	0	0	0
SCTG10	0	0	0	0	4.254867	211.2682	0	0	0
SCTG11	0	0	0	0	0.643628	25.07928	0	0	0
SCTG12	0	0	0	0	3.647224	142.1159	0	0	0
SCTG13	0	0	0	0	3.740241	95.63332	0	0	0
SCTG14	0	0	0	0	0	42.32755	0	0	0
SCTG15	0	0	0	0	0	1	0	0	0
SCTG16	0	0	0	0	0	138.1041	0	0	0
SCTG17	0	0	0	0	46.14806	12.86544	0	0	0
SCTG18	0	0	0	0	46.14806	12.86544	0	0	0
SCTG19	0	0	0	0	222.981	156.6388	0	0	0
SCTG20	0	0	0	0	1133.067	7.601936	0	0	0
SCTG21	0	0	0	0	393.104	0	0	0	0
SCTG22	0	0	0	0	267.6962	0	0	0	0
SCTG23	0	0	0	0	1082.518	0	0	0	0
SCTG24	0	0	0	0	1839.762	0	0	0	0
SCTG25	93.52182	5031.908	0	0	0	0	0	0	0
SCTG26	0	0	0	0	7578.98	0	0	0	0
SCTG27	0	0	0	0	392.5042	0	0	0	0
SCTG28	0	0	0	0	3254.577	0	0	0	0
SCTG29	0	0	0	0	621.0631	0	0	0	561.9978
SCTG30	0	0	0	0	747.4527	0	0	0	0
SCTG31	0	0	0	0	1439.455	9.26281	0	0	0
SCTG32	0	0	0	0	3039.151	0	0	0	0
SCTG33	0	0	0	0	4198.737	0	0	0	0
SCTG34	0	0.067042	0	0	3546.295	0	0	0	0
SCTG35	0	0	0	0	12377.87	0	0	0	0
SCTG36	0	0	0	0	6003.092	0	0	0	0
SCTG37	0	0	0	0	1785.718	0	0	0	0
SCTG38	0	0	0	0	3133.745	0	0	0	0
SCTG39	0	0	0	0	711.9008	0	0	0	0
SCTG40	0	0	0	0	1088.497	0	0	0	0
SCTG41	0	0	0	1.052104	29.10704	0	0	0	8.608894
SCTG43	0.06671	0.041744	0	1.37E-05	0.84238	0.041744	0	0	0.007408
SCTG99	0.06671	0.041744	0	1.37E-05	0.84238	0.041744	0	0	0.007408

Table 8: Use Coefficients by Industry and Commodity

Industry	Agriculture	Construction	Health	Leisure	Manufacturing	Mining	Retail	Wholesale	Service
SCTG01	166.435	8.623	1.006	0.576	11.188	8.623	26.532	26.532	87.325
SCTG02	2.810	7.737	0.583	0.110	8.045	7.737	6.805	6.805	28.851
SCTG03	107.551	182.070	8.192	3.078	105.791	182.070	127.262	127.262	291.450
SCTG04	6.897	4.603	0.353	0.796	17.855	4.603	12.377	12.377	38.949
SCTG05	190.286	8.577	9.624	3.631	60.307	8.577	43.047	43.047	74.914
SCTG06	27.336	3.295	0.003	6.097	57.220	3.295	103.089	103.089	181.644
SCTG07	854.169	16.416	0.240	17.500	727.346	16.416	406.972	406.972	574.950
SCTG08	44.799	1.365	0.018	1.568	104.258	1.365	80.459	80.459	113.579
SCTG09	0	0	0	0	1	0	0	0	0
SCTG10	0.324	0.432	0	0.216	1.807	0.432	9.840	9.840	20.447
SCTG11	0.052	0.034	0	0.025	0.367	0.034	1.138	1.138	2.850
SCTG12	0.292	0.193	0	0.142	2.082	0.193	6.446	6.446	16.150
SCTG13	0.210	0.119	0	0.100	1.519	0.119	5.224	5.224	11.377
SCTG14	0.089	0.271	0	0.006	0.770	0.271	1.391	1.391	1.881
SCTG15	0	0	0	0	1	0	0	0	0
SCTG16	0	14.709	0.001	0.021	5.266	14.709	4.810	4.810	40.067
SCTG17	0	4.504	0.001	0.062	0.214	4.504	0.587	0.587	0.684
SCTG18	0	4.504	0.001	0.062	0.214	4.504	0.587	0.587	0.684
SCTG19	0	19.706	0.002	0.292	10.691	19.706	9.784	9.784	47.663
SCTG20	5.555	6.648	0.003	2.795	124.747	6.648	69.714	69.714	98.951
SCTG21	0.007	0.927	0.003	0.446	54.918	0.927	21.135	21.135	85.901
SCTG22	0	1.962	0	0.427	23.736	1.962	34.287	34.287	21.988
SCTG23	0	2.086	0.004	2.092	130.089	2.086	43.369	43.369	139.217
SCTG24	0	5.313	0.012	10.806	170.388	5.313	71.067	71.067	166.788
SCTG25	1.192	439.025	0.773	0.534	14.600	439.025	84.419	84.419	116.618
SCTG26	4.259	682.990	0.021	44.158	1013.975	682.990	364.036	364.036	492.067
SCTG27	0	13.153	0	0.753	24.780	13.153	14.936	14.936	18.074
SCTG28	0	130.718	0.022	12.418	262.769	130.718	273.317	273.317	271.229
SCTG29	0	3.585	0.421	18.980	63.615	3.585	74.467	74.467	354.167
SCTG30	1.170	1.011	0.001	4.451	44.320	1.011	41.063	41.063	103.563
SCTG31	0	9.376	0.005	8.515	79.061	9.376	117.192	117.192	138.139
SCTG32	0	25.823	0.009	7.868	107.547	25.823	231.599	231.599	225.025
SCTG33	0	13.984	0.020	20.462	189.055	13.984	170.017	170.017	414.986
SCTG34	0	6.001	0.019	16.051	206.897	6.001	139.227	139.227	329.660
SCTG35	0	26.945	0.128	24.231	1573.704	26.945	602.492	602.492	1576.753
SCTG36	0	9.136	0.003	4.341	487.881	9.136	316.719	316.719	294.676
SCTG37	0	1.969	0.012	5.082	149.155	1.969	61.745	61.745	159.730
SCTG38	0	4.902	0.036	19.310	353.619	4.902	111.608	111.608	418.334
SCTG39	0	1.783	0.006	5.501	103.988	1.783	36.846	36.846	84.256
SCTG40	0.547	1.445	0.007	6.542	64.723	1.445	42.580	42.580	122.633
SCTG41	0	0	0	0	0	0	0	0	1
SCTG43	0.054	0.064	0.001	0.010	0.244	0.064	0.144	0.144	0.275
SCTG99	0.054	0.064	0.001	0.010	0.244	0.064	0.144	0.144	0.275

The subsequent disaggregation from counties to zones within the CMAP model area follows the same methodology as the disaggregation from FAF zones to counties. As fewer employment categories are available at the Illiana TAZ level, make/use coefficients of Table 7 and Table 8 were aggregated from eleven to four employment categories. Equations 5, 6 and 7 were used accordingly for the disaggregation from counties to TAZ.

The disaggregated commodity flows in tons need to be transformed into truck trips. Depending on the commodity, a different amount of goods fit on a single truck. FAF² provides average payload factors for four different truck types (Battelle 2002: 29) that were used to calculate number of trucks based on tons of goods by commodity (Table 9).

Table 9: Average Payload Factors by Commodity

SCTG	Commodity	Provided by FAF²	Assumptions	
		Payload (lbs)	SUT	MUT
SCTG01	Live animals and fish	24,492	7,348	68,578
SCTG02	Cereal grains	27,945	8,384	78,246
SCTG03	All other agricultural products	22,140	6,642	61,992
SCTG04	Animal feed or products of animal origin	22,967	6,890	64,308
SCTG05	Meat, seafood, and their preparation	30,691	9,207	85,935
SCTG06	Bakery and milled grains	11,831	3,549	33,127
SCTG07	All other prepared foodstuff	25,926	7,778	72,593
SCTG08	Alcoholic beverages	20,573	6,172	57,604
SCTG09	Tobacco products	25,168	7,550	70,470
SCTG10	Monumental or building stones	25,429	7,629	71,201
SCTG11	Natural sand	29,501	8,850	82,603
SCTG12	Gravel and crushed stones	30,840	9,252	86,352
SCTG13	All other nonmetallic minerals	29,101	8,730	81,483
SCTG14	Metallic ores and concentrates	39,464	11,839	110,499
SCTG15	Coal	43,866	13,160	122,825
SCTG16	Crude petroleum	28,007	8,402	78,420
SCTG17	Gasoline and aviation turbine	48,686	14,606	136,321
SCTG18	Fuel oils	23,442	7,033	65,638
SCTG19	All other coal and refined petroleum	18,608	5,582	52,102
SCTG20	Basic chemicals	29,391	8,817	82,295
SCTG21	Pharmaceutical products	10,260	3,078	28,728
SCTG22	Fertilizers and fertilizer materials	19,833	5,950	55,532
SCTG23	All other chemical products	24,432	7,330	68,410
SCTG24	Plastic and rubber	19,324	5,797	54,107
SCTG25	Logs and other wood in rough	35,073	10,522	98,204
SCTG26	Wood products	18,494	5,548	51,783
SCTG27	Pulp, newsprint, paper, or paperboard	33,046	9,914	92,529
SCTG28	Paper and paperboard articles	26,282	7,885	73,590
SCTG29	Printed products	11,024	3,307	30,867
SCTG30	Textile, leather, and related article	20,608	6,182	57,702
SCTG31	Non-metallic mineral products	31,044	9,313	86,923
SCTG32	Base metal in finished or semi-finished form	24,458	7,337	68,482
SCTG33	Articles of base metal	14,395	4,319	40,306
SCTG34	Non-powered tools	6,064	1,819	16,979
SCTG34	Powered tools	10,698	7,822	73,002
SCTG34	Machinery	26,072	4,146	38,699
SCTG35	Electronic and other electrical equipment	13,821	4,707	43,932
SCTG36	Vehicle, including parts	15,690	10,285	95,990
SCTG37	All other transportation equipment	34,282	2,707	25,267
SCTG38	Precision instruments and apparatus	9,024	4,231	39,488
SCTG39	Furniture, mattresses, lamps, etc.	14,103	4,939	46,094
SCTG40	Miscellaneous manufactured products	16,462	8,734	81,516

SCTG41	Hazardous waste	29,113	5,071	47,326
SCTG41	All other waste and scrap	16,902	5,658	52,805
SCTG41	Recyclable products	18,859	6,522	60,869
SCTG42	Products not classified, blank, not reported or applicable	21,739	3,548	33,113
SCTG43	Mail and courier parcels	11,826	5,739	53,561
SCTG43	Empty shipping containers	19,129	784	7,316
SCTG43	Passengers	2,613	9,980	93,150
SCTG43	Mixed freight	33,268	4,386	40,939
SCTG43	Multiple categories	14,621	7,822	73,002

Unfortunately, these payload factors are only provided for an average truck, while this model distinguishes single-unit und multi-unit trucks. As a result, assumptions were made on the relative difference in payload factors for these two truck types. Based on analysis of payload factors by truck type[5], it was determined that a single-unit truck would carry 90% of the average payload factor and multi-unit trucks are assumed to carry 180% more than the average payload factor.

To split goods flows between single-unit and multi-unit trucks, the traveled distance is used as the explaining variable. This split is based on the assumption that single-unit trucks are more frequently used for short-distance trips, whereas multi-unit trucks dominate the long-distance market. The VIUS data were analyzed to extract the relationship between truck type and distance traveled. The VIUS attribute AXLE_CONFIG distinguishes 44 truck types, where ID 1 through ID 5 (straight trucks and truck tractors not pulling a trailer) were defined as single-unit trucks and ID 5 through ID 64 (straight trucks and truck tractors pulling a trailer) were defined as multi-unit trucks. The VIUS attribute TRIP_PRIMARY describes the trip distance this truck type is primarily used for. Table 10 shows the data summary, where "Off Road", "Not reported" and "Not applicable" were not used in the model application.

Table 10: Truck Type by Primary Distance Class

Truck Type	Off Road	<= 50 miles	51-100 miles	101-200 miles	201-500 miles	>= 500 miles	Not reported	Not applicable
Single-Unit	1%	69%	9%	2%	1%	1%	14%	2%
Multi-Unit	3%	39%	14%	8%	9%	12%	15%	0%

Using the number of VIUS records, these data were converted into share of trucks in each distance bin, shown in Table 11.

5 Based on table 3.2 at http://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_reports/reports7/c3_payload.htm

Table 11: Share of Truck Types by Distance Class

Distance (in miles)	SUT	MUT
0 - 50	82.4%	17.6%
51 - 100	63.3%	36.7%
101 - 200	44.0%	56.0%
201 - 500	26.8%	73.2%
> 500	16.9%	83.1%

The average payload factors and the share of truck type by distance class are combined to convert tons into truck trips.

$$SUT_{i,j} = \sum_{com} \frac{tons_{com,i,j}}{pl_{SUT,com} + \frac{shareMUT_{d_{i,j}}}{shareSUT_{d_{i,j}}} \cdot pl_{MUT,com}} \tag{8}$$

$$MUT_{i,j} = \sum_{com} \frac{tons_{com,i,j}}{\frac{shareSUT_{d_{i,j}}}{shareMUT_{d_{i,j}}} \cdot pl_{SUT,com} + pl_{MUT,com}} \tag{9}$$

where $SUT_{i,j}$ is the number of single-unit trucks from i to j
$MUT_{i,j}$ is the number of multi-unit trucks from i to j
$tons_{i,j,com}$ is the number of tons of this commodity going from i to j
$pl_{SUT,com}$ is the payload factor for SUT for commodity *com* given by Table 9
$pl_{MUT,com}$ is the payload factor for MUT for commodity *com* given by Table 9
$shareSUT_{d_{i,j}}$ is the share of SUT given for distance $d_{i,j}$ given by Table 10
$shareMUT_{d_{i,j}}$ is the share of MUT given for distance $d_{i,j}$ given by Table 10

Furthermore, an average empty-truck rate of 19.36 percent of all truck miles traveled (estimated based on U.S. Census Bureau 2008: 14) was assumed. As FAF[3] provides tons moved, the empty-truck rate needs to be added to the estimated truck trips.

$$totalTruck_{i,j} = \frac{loadedTruck_{i,j}}{1-etr} \tag{10}$$

where $totalTruck_{i,j}$ is the number of total trucks (including empties) from i to j
$loadedTruck_{i,j}$ is the number of trucks carrying freight from i to j
etr is the empty truck rate, currently set to 19.36 percent

Finally, yearly trucks need to be converted into daily trucks to represent an average weekday. As there are slightly more trucks traveling on weekdays than on weekends, a weekday conversion needs to be added.

$$trucks_{daily} = \frac{trucks_{yearly}}{365.25} \cdot \frac{AAWDT}{AADT} \quad (11)$$

where $trucks_{daily}$ is the number of daily truck trips
$trucks_{yearly}$ is the number of yearly truck trips
AAWDT is the average annual weekday truck count
AADT is the average annual daily truck count

Based on ATR (Automatic Traffic Recorder) truck count data the ratio *AAWDT*/*AADT* was estimated to be 1.02159, meaning that the average weekday has just 2 percent more traffic than the average weekend day.

3.2.4 Distribution Centers and Intermodal Facilities

The Chicago region is a major freight transportation hub for northern America. As such, a large number of distribution centers and intermodal transfer centers serve long-distance freight flows by truck, rail, water and air. As there are significant freight facilities in the Illiana study area, it is important to reflect traffic flows generated by these facilities in the freight model.

Figure 7 depicts such flows. Long-distance trips are routed through distribution centers, and short-distance trucks pick up goods from distribution centers and deliver them to destinations in the region. The same concept is applied with flows by rail, water, or air that enter the CMAP model area. Short-distance trucks pick up goods at rail yards, ports and airports and deliver them to their final destinations. It is important to note that truck trips are only routed through distribution centers if they enter the CMAP model area (External-Internal). A flow from Chicago to other regions is expected not to travel through a distribution center. A local manufacturing firm would not use a distribution center to deliver their goods, but rather long-distance trucks pick up the goods at the manufacturing firm. Flows by rail, water or air use intermodal facilities for both directions (External-Internal and Internal-External), as only very few firms have direct on-site access to these modes.

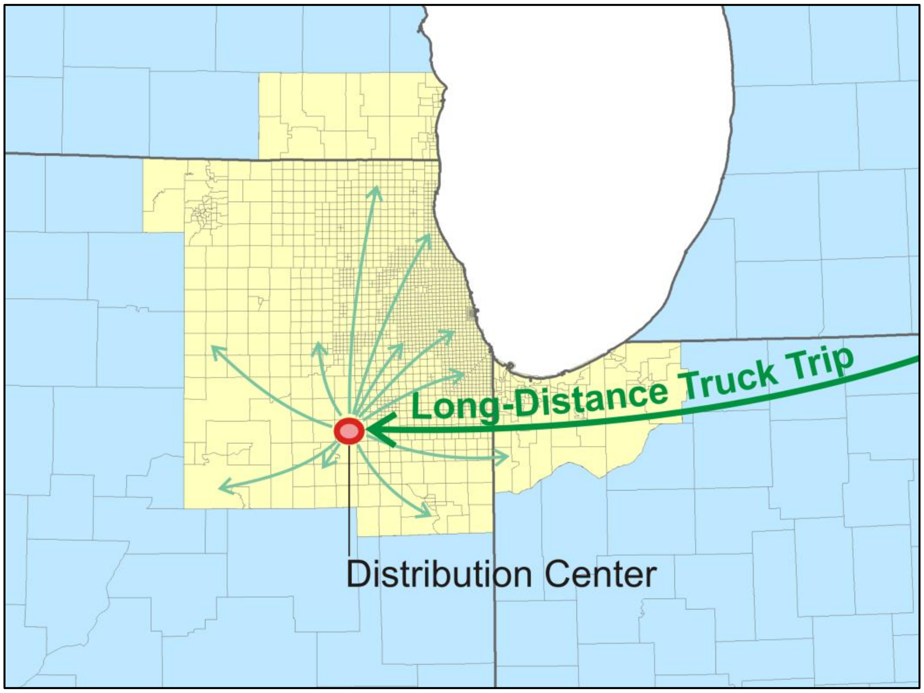


Figure 7: Long-Distance Truck Flows Traveling through Distribution Centers

While intermodal facilities are used for all commodities that enter or leave the CMAP model area by rail, water or air, distribution centers are only used for selected incoming truck flows. Distribution centers are mostly used for smaller scale items in large quantities, such as food or clothing. Larger goods, such as machinery, do not travel through distribution centers, but rather are sent to their final destination directly by the long-distance truck. Building materials, as another example, commonly are shipped to the building site without going through a distribution center either. Mostly, distribution centers are used for retail goods, such as food, paper, or consumer electronics. The share of goods sent through distribution centers by commodity is shown in Table 12. Lacking observed data, these values were assumed for this study.

Table 12: Commodities Traveling through Distribution Centers

SCTG	Name	Share Through Distribution Centers
SCTG01	Live animals/fish	1
SCTG02	Cereal grains	1
SCTG03	Other ag prods.	1
SCTG04	Animal feed	1
SCTG05	Meat/seafood	1
SCTG06	Milled grain prods.	1
SCTG07	Other foodstuffs	1
SCTG08	Alcoholic beverages	1
SCTG09	Tobacco prods.	1
SCTG10	Building stone	0.5
SCTG11	Natural sands	0.2
SCTG12	Gravel	0.2
SCTG13	Nonmetallic minerals	0
SCTG14	Metallic ores	0
SCTG15	Coal	0
SCTG16	Crude petroleum	0

SCTG	Name	Share Through Distribution Centers
SCTG17	Gasoline	0
SCTG18	Fuel oils	0
SCTG19	Coal-n.e.c.1	0
SCTG20	Basic chemicals	0.2
SCTG21	Pharmaceuticals	1
SCTG22	Fertilizers	1
SCTG23	Chemical prods.	0.2
SCTG24	Plastics/rubber	0.5
SCTG25	Logs	0.2
SCTG26	Wood prods.	0.8
SCTG27	Newsprint/paper	1
SCTG28	Paper articles	1
SCTG29	Printed prods.	1
SCTG30	Textiles/leather	0.8
SCTG31	Nonmetal min. prods.	0
SCTG32	Base metals	0
SCTG33	Articles-base metal	0
SCTG34	Machinery	0
SCTG35	Electronics	0.9
SCTG36	Motorized vehicles	1
SCTG37	Transport equip.	0.5
SCTG38	Precision instruments	0.2
SCTG39	Furniture	0.9
SCTG40	Misc. mfg. prods.	0.5
SCTG41	Waste/scrap	0.5
SCTG42	Unknown	0.5
SCTG43	Mixed freight	0.5
SCTG99	Unknown	0.5

Table 13 provides an overview of the use of distribution centers and intermodal facilities. The first block shows inbound trips and the second block shows outbound trips. Each block lists the four modes: truck, rail, water and air, and the long-distance and short-distance truck flows are specified.

Table 13: Use of Distribution and Intermodal Facilities

Direction	Mode	Long-Distance	Short-Distance
Inbound to Chicago region (External to Internal)	Truck	Long-distance truck trip ends at distribution center*	Goods are shipped on smaller trucks from distribution center to final destination within CMAP region
	Rail	Long-distance rail trip ends at intermodal facility (or rail yard)	Goods are shipped on smaller trucks from rail yard to final destination within CMAP region
	Water	Long-distance water trip ends at port	Goods are shipped on smaller trucks from port to final destination within CMAP region
	Air	Long-distance air trip ends at airport	Goods are shipped on smaller trucks from airport to final destination within CMAP region
Outbound from Chicago region (Internal to External)	Truck	Long-distance truck trip travels from CMAP origin to external destination without use of distribution center	None

	Rail	Long-distance rail trip travels from rail yard to external destination	Goods are shipped on smaller trucks from origin in CMAP region to rail yard
	Water	Long-distance water trip travels from port to external destination	Goods are shipped on smaller trucks from origin in CMAP region to port
	Air	Long-distance air trip travels from airport to external destination	Goods are shipped on smaller trucks from origin in CMAP region to airport

(*Truck distribution centers used for selected commodities only as specified in Table 12)

Distribution centers are not used for outgoing truck shipments, as the long-distance trucks commonly leave from the commodity-generating firm on a larger truck to their final destination without reloading within the CMAP model area.

To distribute truck trips across various distribution centers and intermodal facilities, size terms of each were used. For distribution centers, the size term was given by the size of the site in square feet, for ports, the size term was given by number of berth, and for other intermodal facilities (namely rail yards and airports), size was defined by the amount of cargo shipped through the facility by year. The approximate location of facilities and their sizes were given by CMAP. Given that no other direct data were available, CMAP data was used for these facilities.

To calibrate distribution centers and intermodal facilities, constants were added. For the future year 2040, independent studies and planner's insight were used to estimate the number of trucks entering and leaving at selected sites. Estimates were available for nine different sites in four zones. Table 14 shows that these numbers are approximately matched by the model.

Table 14: Calibration of Distribution Centers and Intermodal Facilities in 2040

Name	Type	TAZ	Target	Model	Deviation	Deviation by zone
Elwood	Intermodal	1953	3,627	3,639	0.3%	4%
	Dist. Center	1953	8,073	8,535	5.7%	
Joliet	Intermodal	1592	3,630	3,612	-0.5%	6%
	Dist. Center	1592	12,870	13,911	8.1%	
Crete	Intermodal	1974	1,500	1,475	-1.7%	3%
	Dist. Center	1974	3,500	3,658	4.5%	
Ridgeport Intermodal	Intermodal	2026	2,080	2,019	-2.9%	4%
	Dist. Center	2026	5,920	6,118	3.3%	
Ridgeport Warehouse	Dist. Center	2026	5,500	5,792	5.3%	

It is important to keep in mind that these numbers affect travel flows in the Illiana corridor noteworthy. When evaluating forecasts of traffic flows on the Illiana highway this exogenous forecast for distribution centers and intermodal facilities has to be accepted as a given. Should future growth at these facilities deviate from the forecast shown in Table 14, travel flows in the Illiana corridor will be affected noteworthy.

3.3 Traffic Assignment

The Tier I model uses Caliper Corporation TransCAD's standard multi-modal assignment process to estimate traffic flows for all eight time periods.

3.3.1 2010 Base and 2040 No-Build Assignment

The TransCAD multi-modal multi-class traffic assignment process implements the user-equilibrium assignment method with linear approximation (Frank and Wolfe) in a framework which can handle more than one mode and vehicle class. The basis of the user-equilibrium assignment method is that no traveler can reduce the generalized cost of their trip by unilaterally changing paths.

In the multi-modal multi-class assignment, the Passenger Car Equivalents (PCEs), tolls, operating cost and value of time (VOT) can be set equal to a different value for each mode/class being modeled. Additionally, TransCAD can exclude some modes from using a set of links. In the Tier 1 assignment, all truck modes are excluded from using links in the CMAP area that do not allow truck traffic. Table 15 provides a summary of the PCE, VOT, operating cost, and exclusions by mode. The tolls values are taken directly from the CMAP model, with single-unit truck (SUT) tolls assumed to be 4x auto tolls and multi-unit truck (MUT) tolls assumed to be 10x auto tolls.

Table 15: Traffic Assignment Mode-Specific Parameters

Trip Purpose/ Mode	PCE	VOT ($/min.)	Operating Cost ($/mile)	Exclusions
HBWSOVLI	1.0	$0.20	$0.15	None
HBWHOVLI	1.0	$0.30	$0.15	None
HBWSOVHI	1.0	$0.33333	$0.15	None
HBWHOVHI	1.0	$0.5	$0.15	None
Oth_SOV	1.0	$0.2	$0.15	None
Oth_HOV	1.0	$0.3	$0.15	None
AIRPASS	1.0	$0.5	$0.15	None
ExtAuto	1.0	$0.3	$0.15	None
MTRUCK	2.0	$0.41667	$0.40	No Trucks
HTRUCK	2.5	$0.66667	$0.60	No Trucks
SUT	2.0	$0.41667	$0.40	No Trucks
MUT	2.5	$0.66667	$0.60	No Trucks

The 12 trip purposes/modes are derived from a combination of CMAP Tier II model outputs, the long-distance auto model, and the local and long-distance freight models.

HBWSOVLI trips represent the home-based work trips made in single occupant vehicles (SOV) by low-income households, and HBWHOVLI trips represent the home-based work trips made in vehicles with more than one occupant (HOV) from low-income households. The HBWSOVHI and HBWHOVHI purposes are home-based work trips from high-income households in single-occupant and multiple-occupant vehicles respectively. Low and High Income are defined as below or above the median household income for the region. The Oth_SOV and Oth_HOV modes represent trips that are either home-based but not work-related or non-home-based in SOVs and HOVs. These first six trip purposes are generated by the Tier II CMAP model procedures, as will be discussed later, and the AIRPASS mode is a special generator in the CMAP model showing trips to and from the major airports in the CMAP area.

The ExtAuto mode gives the long-distance auto trips from the NELD model, and the SUT and MUT modes give the single-unit truck and multi-unit truck trips generated by the FAF3 national truck model. The final two modes, MTRUCK and HTRUCK, represent the single-unit truck and multi-unit truck trips from the Local Freight Model.

The same values for PCE, VOT, Operating Cost, and Exclusions were used in the 2010 Base, 2040 No-Build, and 2040 Build assignment runs using the Tier II CMAP results for those networks. Further discussion of the correspondence between the TransCAD trip purposes and CMAP trip purposes is included in Section 4.1.3. Section 3.3.2 covers the development of the inputs to the 2040 Build network models and additional procedures used only in the 2040 Build assignments.

In order to achieve the highest level of accuracy, the model is run separately for each of eight time periods. The time periods used are the same as those included in the CMAP model: 8pm to 6am (Period 1), 6am to 7am (Period 2), 7am to 9am (Period 3), 9am to 10am (Period 4), 10am to 2pm (Period 5), 2pm to 4pm (Period 6), 4pm to 6pm (Period 7), and 6pm to 8pm (Period 8). The different traffic patterns experienced during each of these time periods create different levels of congestion, the effects of which are not captured when the demands and capacities are aggregated to daily levels. The outputs of these assignment results are then processed at three levels for comparison and calibration: daily flows, peak flows, and off-peak flows. Time periods 3 and 7 (7am to 9am and 4pm to 6pm) are used to represent the peak traffic periods. The other time periods are included as off-peak flows.

3.3.2 2040 Build Assignments

The testing of the initial alternatives required TransCAD to select only those links associated with each build alternative. Each of the initial limited access highway and arterial alternatives were are all coded into one master network with a field indicating which initial build alternative each link was used in. An additional step is added to the assignment process for these build networks to select only the links corresponding to the alternative being tested. Links not used in the initial build alternative being run will not be included and will, therefore, have no flow. This ensures that the rest of the network is identical for each build alignment being tested and the only factor changing is which build alternative links are used.

In order to account for the reallocation of regional population and employment that could result from the increased accessibility provided by the finalist Illiana corridor alternatives carried forward to the Tier One Draft Environmental Impact Statement, the generalized cost skims between CMAP zones for the No-Build and Build alternative scenario were developed in order to estimate zone-to-zone travel time changes between the scenarios. Those time savings are then applied to generate new socioeconomic data for the CMAP region, which serve as inputs to Tier II CMAP model runs for 2040 Build Alternative runs, including the NELDT, FAF3, and local freight models.

3.4 Model Calibration

To assess the reasonability of model results, model calibration compares simulated volumes with observed volumes. Count data were not used in model development, ensuring that the validation step uses independent data.

3.4.1 Traffic Count Data

Given the size of the CMAP area and the need for additional count detail in the Illiana corridor especially, a combination of count data from multiple sources was used in the calibration phase. The original CMAP counts were the primary source, but addition counts were gathered from INDOT, IDOT, WisDOT, and from consultants in the course of the study to provide a more complete set of counts on both freeway and arterial roadways. The date that the counts were collected ranges from 1998 to 2011, and some priority was given to the truck counts that were collected in 2011. The number of links with counts by region and roadway type is shown in Table 16.

Table 16: Number of Counts by Region and Roadway Type

1 ILNA STUDY AREA (D1,2,7)	Autos	Truck All	Truck Large	Truck Medium	All
Freeways	55	55	55	55	84
Arterials	205	218	218	218	729
TOTAL	260	273	273	273	813
2 ILNA SOUTHERN (D3-6,8-11)	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	225	226	226	226	499
Arterials	533	667	667	667	1,599
TOTAL	758	893	893	893	2,098

3 OTHER CMAP AREA	Autos	Truck All	Truck Large	Truck Medium	All
Freeways	640	642	642	642	902
Arterials	1,031	1,167	1,167	1,167	3,470
TOTAL	1,671	1,809	1,809	1,809	4,372
Total 22 County Region	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	920	923	923	923	1,485
Arterials	1,769	2,052	2,052	2,052	5,798
TOTAL	2,689	2,975	2,975	2,975	7,283

Due to the high number of counts and variety of sources, there are some links that have multiple counts provided by different sources. In these cases, the count closest to the modeled daily flows (sum of the 8 time-period flows) on that link is selected for calibration.

The count data is given in average daily traffic values for total vehicles and heavy commercial vehicles (trucks). While fewer links had counts for commercial vehicles, those available are segmented into single-unit trucks and multi-unit trucks, allowing for a more detailed truck calibration process. In order to calibrate the auto modes separately from the trucks, the number of autos is also calculated on links with both total vehicle and truck counts.

Since all counts are given in units of an average day, the assignment results are summed to calculated daily flow values on each link. The flows are then summed by purpose in order to produce a set of auto, SUT, MUT, and total vehicle flows on each link for calibration.

3.4.2 CMAP Auto Calibration

The first stage of the calibration process was to check the validity of some of the counts. Counts that varied by an order of magnitude from adjacent counts were examined closely and removed or changed if an error was discovered. After that process was complete, the set of 100 links with the largest error between the modeled flows and counts were examined and either accepted, replaced, or removed based on whether they appeared to be realistic based on neighboring links and observed conditions on the actual roadways. Once this phase was completed, the calibration moved on to other methods to match the flows to ADT and HCV counts.

In the early calibration stages, it was clear that flows were significantly lower than counts in the southern portion of the CMAP model area, while the flows matched counts more closely in the northern CMAP model area. One solution that was tested to increase the flows in the southern corridor was to inflate the trips using select links which cross into that region by

15%. Unfortunately, this method resulted in only a marginal increase in traffic on links in the southern corridor. The second method used to adjust the trip tables in order to account for this regional bias was to scale the trip tables by region. The primary reason that this was necessary is the added detail in the Tier I network model. The Tier II model provides more aggregate trip tables that must be disaggregated to match the Tier I zone system. Due to this difference in the zonal detail between the trip generation network and the assignment network, the trips in the southern area, especially in the study area are under-represented. Various scaling methods were used, and the final factors are shown in Table 17.

Table 17: Trip Table Scaling Factors

Origins	1 ILNA STUDY AREA (D1,2,7)	2 ILNA SOUTHERN (D3-6,8-11)	3 OTHER CMAP AREA
1 ILNA STUDY AREA (D1,2,7)	**1**	1	1.1
2 ILNA SOUTHERN (D3-6,8-11)	1	**1.2**	1.15
3 OTHER CMAP AREA	1.1	1.15	**1.1**

The third phase of calibration involved changing link attributes to shift flow from arterials (which had flows higher than counts) to freeways (which had flows less than counts). The first method attempted was to adjust the Beta values used in the VDF function. The Beta values are the same as those adopted in the generalized cost function of the CMAP model, and the cost function in this model penalizes freeway congestion more heavily than arterial congestion by using a Beta value of 8 for freeway and expressway links and 4 on arterial links. The first calibration measure tested was to adjust the freeway Beta values from 8 to 7 and increase the arterial Beta values from 4 to 6. While this did have some effect on balancing the flow, it was minimal. Therefore, this measure was not included in further calibration steps.

The fourth step of the calibration process was to attempt to fix the disproportional assignment of flow to arterials by scaling the arterial speeds down and scaling the freeway ramp speeds up. The freeway ramp speeds were factored by 1.25 while the arterial speeds were factored by 0.9. Another link speed scaling method tested was to scale only the speeds on principal arterials. The principal arterial speeds were scaled by 1.12 up to a maximum of 55mph. This was done after further comparison revealed that the arterial flows were unevenly split between major and minor arterials. Both of these speed adjustments did improve the balance between freeway, major arterial, and arterial flows, but as other measures were introduced, the flows became more balanced with the original speeds. For that reason, in the final calibration phase, the speeds were all set to their original values.

The final two calibration methods tested and implemented were the changing of the toll scales and changing the VOT by trip purpose. The toll values given on each link are SOV tolls, so to calculate the SUT and MUT toll values, a scaling factor is applied to the SOV toll. The initial scaling factors applied were 4 times SOV tolls for SUTs and 7 times SOV tolls for MUTs. After further research into the actual toll rates on some Illinois and Indiana roadways, however, it was determined that the MUT tolls should be equal to 10 times the SOV tolls instead of 7.

After these other changes were made, comparisons of flows to counts by roadway type and by tolled and non-tolled roads indicated that the value of time (VOT) used by trip purpose should be adjusted slightly. The original and final set of VOT values are shown in Table 18.

Table 18: Value of Time Adjustments

Trip Purpose/ Mode	VOT Final ($/min.)	VOT Final ($/mile)
HBWSOVLI	$0.20	$0.15
HBWHOVLI	$0.30	$0.15
HBWSOVHI	$0.33333	$0.15
HBWHOVHI	$0.5	$0.15
Oth_SOV	$0.2	$0.15
Oth_HOV	$0.3	$0.15
AIRPASS	$0.5	$0.15
ExtAuto	$0.3	$0.15
MTRUCK	$0.41667	$0.40
HTRUCK	$0.66667	$0.60
SUT	$0.41667	$0.40
MUT	$0.66667	$0.60

The final set of adopted calibration measures for auto trips are presented in Section 3.4.5.

3.4.3 Long-Distance Auto Trip Calibration

Long-distance auto trips cannot be validated within the study area, as traffic volumes inside the study area are a combination of short-distance and long-distance traffic. Thus, inside of the CMAP study area, only total autos (short-distance plus long-distance) can be validated. To understand how reasonable the long-distance auto model performs, traffic volumes are validated at the external stations of the CMAP model area. Only vehicles generated by the long-distance auto model may cross the external stations of the CMAP area, thus true validation of the long-distance model becomes possible.

Unfortunately, count data were not available at all external stations, making it difficult to capture a complete picture. Auto counts were collected from DOT websites of WisDOT, IDOT, INDOT and MDOT, count data could be retrieved for 39% of all external stations of the CMAP model area. Summary statistics shown in Table 19 exhibit a reasonable performance of the national long-distance model.

Table 19: Validation of Long-Distance Autos at External Stations of CMAP Model Area

Measure	Value
Total autos observed	189,638
Total autos modeled	193,641
Deviation between autos observed /modeled	+2%
R2	0.489
Root Mean Square Error (RMSE)	3,340
Percent RMSE	51%

Flows were further analyzed by direction. Table 20 shows a summary distinguishing states and general direction. The second column sums up available count data at external stations, and the "Model" column sums up simulated volumes at external stations where count data were available. The column count availability shows for how many external stations count data were available. Michigan had count data for the majority of external stations, and Indiana covered all external stations, giving high confidence in the validation data. In Wisconsin, available count data were very limited, not true validation may be done for auto flows leaving the study area to the north.

Table 20 Validation of Long-Distance Autos at External Stations by Direction

State	Count	Model	Count Availability	Diff
MI	22,320	23,058	75%	3%
IN east	28,832	29,657	100%	3%
IN south	34,786	33,669	100%	-3%
IL south	42,550	43,644	47%	3%
IL west	38,000	37,757	29%	-1%
WI west	23,150	25,856	15%	12%
WI north			0%	
Total	189,638	193,641	39%	2%

Given that the Illiana study area is located in the southern part of the CMAP study area, limited calibration of flows to and from Wisconsin is less relevant for this study. The validation of flows entering and leaving the CMAP model area from and to Illinois and Indiana suggests that the auto long-distance model reflects well person long-distance travel.

3.4.4 Truck Trip Calibration

To validate the model, assigned traffic flows are compared to count data. While this validation was fairly straightforward on the auto side, truck counts showed limited usability. Different count sets with unknown progeny told different stories on truck travel. Furthermore, truck count data within the city of Chicago showed a different match than truck count data in the Illiana study area. In the end, it was decided that matching count data in the corridor is more relevant for this analysis than matching counts in the city of Chicago.

Table 21 shows major measurements to compare modeled volumes with count data. Two different count data sets for total trucks were available, as well as a few counts where single-unit trucks (SUT) and multi-unit trucks (MUT) could be distinguished. These datasets show different truck volumes, and could not be reconciled. With Root Mean Square Error (RMSE) being the more relevant measure, Will County is represented consistently better than the total study area. Analyses of the count data suggest that this difference is due to inconsistencies in the count data.

Table 21: Summary of Illiana Truck Validation in Will County and in CMAP Area

Count Dataset	Measure	Will County	CMAP Area
1	Number of counts	347	2,683
	R2	0.380	0.535
	RMSE	1,607	2,099
2	Number of counts	475	4503
	R2	0.648	0.558
	RMSE	1,729	3,649
SUT	Number of counts	283	2,033
	R2	0.506	0.446
	RMSE	558	1,398
MUT	Number of counts	283	2,031
	R2	0.336	0.154
	RMSE	596	1,766

3.4.5 Adopted Calibration Methods and Results

The final values of trip table scaling used are shown in Table 17, and the final set of assignment parameters used is in Table 15. After the calibration measures presented and discussed in Section 3.4.2 were finalized, the assignment is run with these values of trip table scaling and VOT. Link speeds and Beta values are equal to their original values, and the SUT toll is set to 4 times the SOV toll, while the MUT toll is set to 10 times the SOV toll. The resulting assignment provides flows which are described in two tables below.

Table 22 presents the mean percent error, equal to the average difference between flows and counts for links by link type and by region, divided by the average count value on links of that type in each region. This table includes results for primary and other arterials separately, but it is important to note that the primary arterial designation was only available for links in the southern corridor. Arterial links in the remainder of the CMAP model area were not split into major and minor arterials.

Table 22: 2010 Final Calibration Results – Mean Percent Error

1 ILNA STUDY AREA (D1,2,7)	Autos	Truck All	Truck Large	Truck Medium	All
Freeways	9.2%	-0.5%	-4.1%	18.3%	-1.2%
Principal Arterials	-6.1%	-12.7%	-6.1%	-20.2%	-4.9%
Arterials (Other)	4.6%	-29.9%	-1.1%	-54.3%	-9.9%
TOTAL	**2.8%**	**-10.5%**	**-4.1%**	**-23.6%**	**-5.6%**
2 ILNA SOUTHERN (D3-6,8-11)	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	-35.2%	-1.4%	-14.0%	45.1%	-22.7%
Principal Arterials	-19.0%	18.3%	18.2%	18.4%	-21.0%
Arterials (Other)	-11.4%	24.4%	24.2%	24.4%	-4.0%
TOTAL	**-22.4%**	**8.9%**	**-3.4%**	**31.3%**	**-12.3%**
3 OTHER CMAP AREA	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	-37.1%	28.0%	-7.9%	109.8%	-24.8%
Arterials	0.7%	70.4%	69.8%	70.8%	10.8%
TOTAL	**-20.9%**	**46.1%**	**16.6%**	**87.0%**	**-4.9%**
Total 22 County Region	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	-36.0%	18.7%	-9.5%	93.6%	-23.8%
Principal Arterials	-14.3%	1.8%	4.1%	-0.5%	-13.6%
Arterials (Other)	-2.2%	56.2%	56.3%	56.2%	6.6%
TOTAL	**-20.6%**	**33.5%**	**9.8%**	**69.3%**	**-6.8%**

It is clear from the results in

Table 22 that the Study Area is the most well-calibration region. More care was taken to calibrate flows to counts in the Study Area, since this is the most vital region in testing build alternatives in Tier III of this work. Additionally, we can see that in the study area, freeway flows are generally higher than counts, while in the remainder of the network the opposite is true. This is due in part to the scaling of trip tables in the Study Area, and in part to the presence of more freeways in the ILNA Southern and Other CMAP regions with higher levels of congestion. Additionally, it is clear that the total number of autos is quite a bit lower than counts would indicate outside the Study Area. While some attempts were made to fix this issue with the trip table scaling, the final scaling factors chosen provided the best match to counts of all sets of factors tested.

In order to capture the dispersion of these errors, the percent root mean squared error is also given in Table 23. This is necessary to include due to the fact that flows which exceed counts and flows which are significantly less than counts will balance out when using the average difference as in

Table 22. This may lead to some regions and roadway types appearing more calibrated than they truly are.

Table 23: 2010 Final Calibration Results - Percent RMSE

1 ILNA STUDY AREA (D1,2,7)	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	34.0%	49.0%	53.2%	59.8%	28.3%
Principal Arterials	54.3%	107.1%	148.3%	77.2%	41.0%
Arterials (Other)	57.9%	91.5%	126.8%	106.2%	84.8%
TOTAL	**48.2%**	**78.1%**	**94.7%**	**85.8%**	**53.4%**
2 ILNA SOUTHERN (D3-6,8-11)	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	49.4%	53.5%	55.0%	116.9%	41.3%
Principal Arterials	41.6%	80.1%	107.4%	68.5%	43.4%
Arterials (Other)	45.8%	121.8%	190.4%	93.6%	51.3%
TOTAL	**50.1%**	**84.4%**	**99.0%**	**107.0%**	**48.3%**
3 OTHER CMAP AREA	**Autos**	**Truck All**	**Truck Large**	**Truck Medium**	**All**
Freeways	51.0%	120.9%	101.7%	204.7%	43.5%
Arterials	36.1%	167.3%	224.9%	144.3%	47.8%
TOTAL	**51.1%**	**146.4%**	**146.5%**	**177.3%**	**51.8%**

Total 22 County Region	Autos	Truck All	Truck Large	Truck Medium	All
Freeways	52.4%	103.6%	86.9%	193.4%	44.8%
Principal Arterials	48.4%	94.5%	131.7%	73.8%	45.6%
Arterials (Other)	39.3%	162.7%	221.8%	139.6%	50.5%
TOTAL	**53.4%**	**135.4%**	**135.3%**	**170.7%**	**53.0%**

As Table 23 demonstrates, the overall level of calibration does not vary greatly across regions. The only noticeable difference is that the error on freeways in the Study Area is smaller than in other areas. It is also clear that the auto flows are generally closer to the auto counts than truck flows. This is due in part to limitations on the ability of models to account for all truck limitations. In many areas, trucks may use a freeway, but they are only permitted in certain lanes. Unfortunately, there is no means of accounting for such restrictions in a TransCAD traffic assignment model. This leads to error in the number of trucks modeled on some roadways and in the distribution of trucks across freeways and arterials. Overall, however, given the complexity of the model and the variety of sources and years of the counts, these error measures were deemed reasonable for the final calibrated model.

4.0 Tier II: CMAP Model

The CMAP travel demand model has been developed for the Chicago metropolitan region over decades. It has been adapted and calibrated for the Illiana Corridor Study analysis. However, the current CMAP model covers auto travel, with trucks given exogenously by a synthesized truck matrix. To ensure full model sensitivity, a local truck model was developed to replace the static truck matrix.

4.1 CMAP Person Travel Demand Model

The steps of a full CMAP travel forecasting model run are illustrated in Figure 8. The following sections will discuss in more detail the elements of this model that are updated and used in the Tier II model and how they relate to the Tier I model.

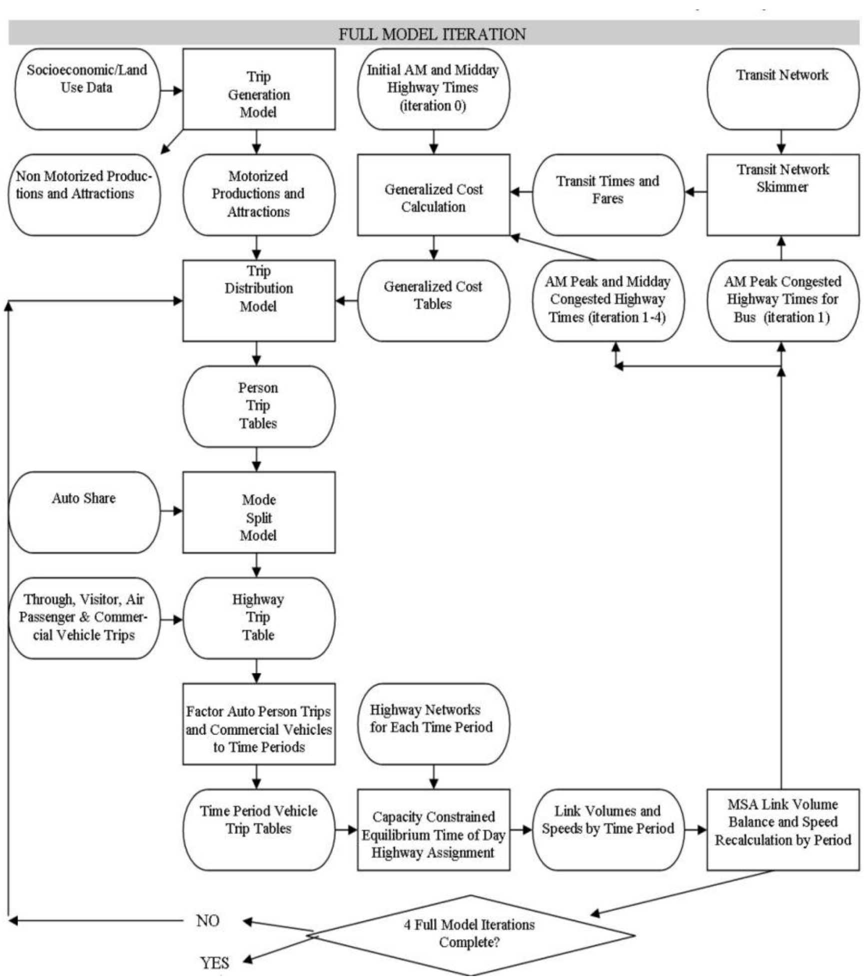


Figure 8: CMAP Model Procedure Steps

For more details on the CMAP travel model, see the "CMAP Travel Model Documentation[6]".

4.1.1 SED and Network Data

For each CMAP travel model run, the socioeconomic data and transportation network associated with that build alternative and year are required inputs. For this project, the travel model was run using different scenarios, including a 2010 Base Year, a 2040 No-Build (Baseline) scenario, and 2040 Build Alternative scenarios. For each of these scenarios, the SED was compiled from a forecast model based on predicted changes by county, township, and zone. These data sets were estimated and provided by The al Chalabi Group.[7]

Once the input data sets were prepared, the full four-iteration model run was completed for each scenario. The network changes included those committed projects that were added to the 2040 No-Build network in TransCAD. Those links were also added to the CMAP network for the 2040 No-Build and Build model runs in order to produce the most accurate trip tables possible to be used in the 2040 No-Build TransCAD assignment phase in Tier I.

4.1.2 CMAP Model Run Outputs

Once the full CMAP model run is complete, EMME can export the resulting trip tables as a series of files that contain the trips by purpose. These are then processed into a *.csv file that provides the number of daily trips produced by each origin zone and attracted to each destination zone. These production-attraction (PA) tables are generated in the Tier II zone system, so an addition disaggregation step, described in Section 3.1.6, is used to convert the Tier II model outputs into the Tier I zone system.

At this stage, the Tier II model outputs have been converted to the Tier I zone system, but they still include all of the CMAP trip purposes, and they are in daily PA format. The inputs to the Tier I traffic assignment require fewer trip purposes in order to decrease the running time of the model. Furthermore, the Tier I model inputs must be in origin-destination (OD) format and provided by time-of-day. A table of factors is used to convert the trip tables into time-period OD format, using a vehicle occupancy factor to convert from person trips to vehicle trips, transpose and return-rate factors to convert from PA format to OD format, and period factors to allocate a portion of the daily trips to each time period. Additionally, special factors are included for trips to and from the central business district (Chicago) and to and from airports. All of these factors were provided by CMAP and combined to generate the Tier I trip purposes as necessary.

---

[6] http://www.cmap.illinois.gov/modeling

[7] The al Chalabi Group, "Historic and Forecasted Growth of Employment and Population in the Extended Region of Chicago," February 2012

4.1.3 Trip Purposes

In the Tier I model, trips are assigned to the full national network with a special focus and additional detail in the CMAP model area. Due to the high number of zones (3,859) and links (199,608) that this results in, the CMAP trip purposes were consolidated in order to allow for fewer modes in the TransCAD Tier I assignment. Additionally, the freight trips are modeled separately from the CMAP model in this project. Therefore, the truck trips generated by the CMAP travel forecasting model are not assigned to the Tier I model. Table 24 below provides a reference between the CMAP modes and Tier I assigned modes.

Table 24: Tier II to Tier I Trip Purpose Correspondence

Source	Model Tables			To ->	Assigned Tables	
CMAP	1	SOV	HBW-Low	1	1	HBWSOVLI
	2		HBW-High	2	2	HBWSOVHI
	3		HBO	3	3	Oth_SOV
	4		NHB	3		Oth_SOV
	5	HOV2	HBW-Low	4	4	HBWHOVLI
	6		HBW-High	5	5	HBWHOVHI
	7		HBO	6	6	Oth_HOV
	8		NHB	6		Oth_HOV
	9	HOV3+	HBW-Low	4		HBWHOVLI
	10		HBW-High	5		HBWHOVHI
	11		HBO	6		Oth_HOV
	12		NHB	6		Oth_HOV
	13	AirPassVehicles		7	7	AIRPASS
Long Distance Model	14	AUTO External		8	8	ExtAuto
CMAP	15	B-Trucks			Excluded	
Internal Truck Model	16	Light Trucks	LTRK_I		Excluded	
	17	Medium Trucks	MTRK_I	9	9	MTRUCK
	18	Heavy Trucks	HTRK_I	10	10	HTRUCK
Long Distance Model	19	SUT	SUT_L	11	11	SUT
	19	MUT	MUT_LIE (IE/EI) MUT-LEE (EE)	12	12	MUT

Although the Tier I set of trip purposes do not provide the same level of disaggregation between number of passengers in an HOV trip, they do retain the distinction between low-income and high-income work trips. Assigning these income groups separately allows for more detailed comparisons of alternatives and more accurate measures of improvement in the network. Additionally, we assume that the B-Trucks and Light Trucks from the CMAP and Internal Truck Models will be included in the Auto trips and other truck trips.

4.1.4 Growth in Trips from 2010 Base to 2040 No-Build

The network changes and predicted SED values in the 2040 No-Build network both result in changes to the number of trips of each purpose generated in the network. Those increases are presented in Table 25 with the percent growth in trips summarized by CMAP district and the purposes aggregated to Auto Trips, Truck Trips, and Total Vehicle trips.

Table 25: Percent Growth in Trips from 2010 Build to 2040 No-Build by District

District	Auto Trips	Truck Trips	All Vehicle Trips
1	251%	444%	266%
2	51%	69%	52%
3	11%	12%	11%
4	32%	42%	33%
5	-12%	24%	-10%
6	32%	70%	34%
7	56%	78%	57%
8	6%	26%	7%
9	132%	168%	134%
10	67%	121%	70%
11	23%	35%	24%
12	5%	13%	6%
13	33%	47%	34%
14	28%	39%	28%
15	41%	55%	41%

District 5, which generates fewer trips in the 2040 No-Build scenario than in 2010 showed negative economic growth in many regions of the district in 2040. These economic factors are the inputs to generating and attracting trips in the CMAP Tier II model, so the districts with little or negative growth in trips correspond to those with little or negative growth in employment, population, and/or other SED factors. Additionally, it is important to notice that in all districts, the percent increase in truck trips was greater than the increase in auto trips. This is due to the fact that the truck model considers other factors not included in the auto trip model, such as the addition of distribution centers that would generate more truck trips in some districts.

4.2 Local Truck Model

The short-distance truck model is built following the paradigm of a three-step Quick Response Freight Manual (QRFM [8] model, as published by the Federal Highway

[8] Beagan, D., Fischer, M., Kuppam, A. (2007) Quick Response Freight Manual II. FHWA: Washington, D.C.

Administration (FHWA). This model generates truck trips based on composite trip production and attraction rates from several metropolitan areas, and distributes trips using a distance-based gravity model.

While the CMAP model works with two employment categories (retail and total employment), the QRFM approach requires four employment categories. As described in section 3.2.3, more detailed employment categories were derived using Dun & Bradstreet employment data for the long-distance model. These more detailed data were used by the local truck model as well.

QRFM trip generation rates are based on a truck survey conducted for Phoenix, AZ in 1992. Given the age of the data on the geographic differences between Phoenix and Chicago, adjustments to trip generation rates were necessary. Very few data were available for this adjustment in the Chicago region. Counts by truck type were used to scale trip generation rates provided by QRFM. While multi-unit truck trip generation rates could be used without adjustment, single-unit truck trip generation rates had to be reduced for the Illiana model.

Table 26: Short-Distance Truck Trip Generation Rates

Industry	Single-Unit Trucks		Multi-Unit Trucks	
	QRFM	Illiana	QRFM	Illiana
Agriculture, Mining, and Construction	0.289	0.173	0.174	0.174
Manufacturing, Transportation/ Communications/Utilities, and Wholesale	0.242	0.189	0.104	0.104
Retail Trade	0.253	0.104	0.065	0.065
Office and Services	0.068	0.055	0.009	0.009
Households	0.099	0.099	0.038	0.038

The short-distance truck model is constrained to simulate trips of 50 miles or less only. Long-distance trips of more than 50 miles are covered by the long-distance truck model, as described in section 3.2.

The trip length was calibrated to match the average trip length in miles summarized from the current CMAP trip matrices. The values were also compared to those reported in the QRFM and the VIUS[9] by adjusting the γ parameter of the gravity model. The average trip lengths were adjusted downward to match commercial vehicle miles of travel by county reported by the Illinois DOT.

[9] Vehicle Inventory and Use Survey, 2002, http://www.census.gov/svsd/www/vius/2002.html

Table 27: Calibration of Trip Length of Short-Distance Truck Trips

Truck type	QRFM	VIUS	Illiana model
Single-Unit Trucks	27.51	19.17	14.91
Multi-Unit Trucks	30.81	20.94	16.44

The resulting trip tables contain single-unit and multi-unit truck trips under 50 miles and are fed into the multi-class assignment.

5.0 Tier III: Illiana Corridor Model

The size and complexity of the full Tier I network allow for more accurate modeling of overall flow patterns for each scenario year. However, when testing various scenarios on build alternatives and tolling alternatives, the model complexity becomes an issue. The full Tier 1 model requires approximately 8 hours to reach convergence. In order to test alternatives on the build networks quickly, it is preferable to use an extracted subarea network and trip tables. When the full assignment is run on the subarea instead of the full Tier I network, the run time decreases to less than 1 hour, allowing multiple alternatives to be testing in the same span of time.

5.1 Subarea Definition

The subarea extracted for the more detailed Tier III includes districts 1 through 11 and the lower portion of district 12. Figure 9 shows a map of the districts with the district number displayed on each, and the blue line denotes the subarea. The subarea boundaries were chosen based on a combination of district boundaries and roadway geography.

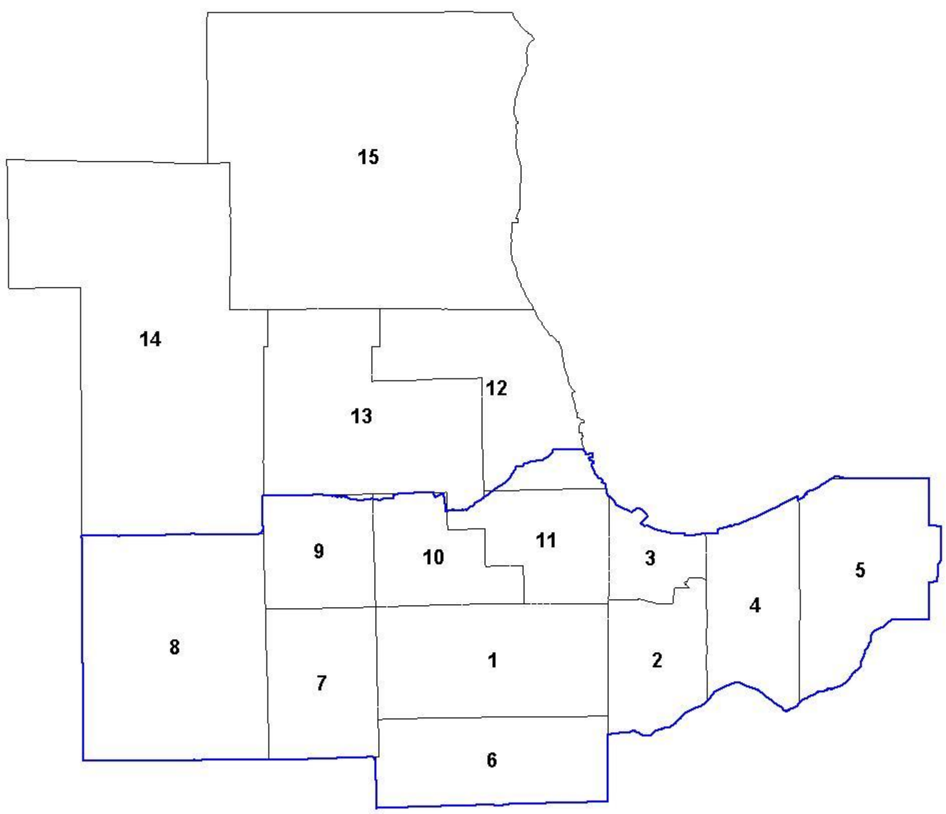


Figure 9: Subarea to District Correspondence

The subarea boundary in district 12 is drawn just South of I-55 so that the majority of the Chicago area is not included. This subarea was chosen as the region where the greatest effects of changes to build alternatives would be seen. This allows one set of subarea trip tables to be applied to multiple build alternatives in the subarea network as the trips outside the subarea are not expected to change significantly as a result of changes to the build freeway links.

5.2 Subarea Extraction in TransCAD

The subarea extraction process in TransCAD is completed in two phases. The first phase is to create a subarea network. TransCAD does this by determining which links fall inside the subarea and which are located on the subarea boundary. The boundary and internal links are all exported, with all boundary links denoted as external connectors. The nodes are similarly selected as those inside the subarea and those outside of the subarea which are endpoints to boundary links. Those nodes which are endpoints on boundary links and are located outside of the subarea boundary are then stored as external centroids, so that the trip tables generated in the second phase of the subarea extraction include trips between all of the new external centroids.

The extracted subarea network has 13,055 links, 925 internal centroids, and 122 external centroids. This is just over 6.5% of the links and just over 27% of the number of centroids in the full Build network. This decrease in the number of links and centroids greatly decreases the time required to run assignments on the network and to process the assignment results.

The second phase of the subarea extraction process is the generation of subarea trip tables. This is done by performing a full assignment run on the original network while treating all boundary links as select links. The select link analysis results indicate how much flow across each of the boundary links is from each OD pair. This data allows TransCAD to compress the original trip tables into subarea trip tables with trips between subarea centroids (including external centroids). The resulting trip tables can be assigned to the subarea network, and they should provide the same flows as the subarea extraction assignment.

Appendix 1 – ILNA Modeling Flow Chart

Illiana EIS – Modeling Flow Chart