San Joaquin Valley Sustainable Implementation Plan

Commercial Truck Modeling White Paper:

Recomended Framework for Freight Modeling in the Valley

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INTRODUCTION

The purpose of this white paper is to provide guidance and recommendations for the regional transportation planning agencies (RTPAs) in the San Joaquin Valley as to how to develop and maintain a Valleywide freight/commercial vehicle model. The first Valleywide truck model was developed in the early 2000's and has undergone several revisions since that time. However, contacts with the planning and modeling staff within the RTPAs indicate that the model is not being widely used for a variety of reasons, including concerns about the quality of the outputs and a lack of an institutional mechanism to maintain and update the model and to train new staff. To some degree this has been the result of insufficient demand for using the model in the past. But this is changing and there are a growing numbers of studies, plans, and performance measure reporting requirements for state and federal funding programs that would benefit from a more robust freight model that could be better integrated in the Valley planning programs. This new interest in freight modeling was the impetus for this white paper. The white paper was intended to review the state-of-the-practice in freight/commercial vehicle modeling, to review the existing Valleywide truck model, and to make recommendations for next steps to improve the model and support its ongoing application.

Freight and commercial vehicle modeling practices and techniques have improved significantly in the last decade. This is related to the growing interest by public agencies in understanding the impacts of economic growth and goods movement on traffic conditions and performance of major facilities, as well as the requirements by state and federal surface transportation legislation to consider goods movement needs as part of the transportation planning process.

OVERVIEW OF FREIGHT/COMMERCIAL VEHICLE MODELING STATE-OF-THE PRACTICE

The growing demand for various freight-related analysis from public agencies resulted in significant improvements in in the availability of freight-related data sources such as accessibility and affordability of truck GPS data and truck diaries, increase in data quality and sample size of freight related surveys such as, local establishment surveys, and national and local commodity flow/ origin-destination studies. Currently, the Federal Highway Administration and the Bureau of Transportation Statistics are considering re-establishing the Vehicle Inventory and Use Survey (VIUS), while at the state level, California is in the process of conducting its own statewide VIUS program to provide data for state and local freight modeling. The National Cooperative Freight Research Program (NCFRP), the National Cooperative Highway Research Program (NCHRP), and the Strategic Highway Research Program (SHRP) have all conducted applied research projects to advance the state-of-the-art of freight modeling, and an increasing number of states and metropolitan planning organizations (MPOs) have adapted methodologies from this research in state and regional freight models.

Prior to developing the modeling framework for new freight/commercial vehicle models, it is useful to review existing literature on freight and truck travel modeling in order to identify conceptual frameworks that could be useful in the San Joaquin valley as well as pitfalls that should be avoided. This report reviews and summarizes the modeling techniques that are currently being used by various MPOs and States. The ensuing sections provide a brief description of the various techniques identified in those reviews.

The modeling techniques can be generally classified into the seven categories (A-G) based on objective, methodology, and data requirements as shown Table 1. The models are ordered by complexity:

A- Link-based factoring model, where future traffic volumes are estimated by factoring the base year traffic counts and a fixed growth rate.

B- Origin-destination (O-D) factoring model, where future truck flows are estimated by factoring the base year O-D matrix and a fixed growth rate.

C- 3-step truck models with similar steps to traditional passenger travel demand model; trip generation, trip distribution and traffic assignment.

D- 4-step commodity models relates are similar to group C with an extra step of mode choice or mode split before network assignment.

E- Economic activity models include an economic or land use model as a step before the traditional four steps.

F- Tour-based model with similar concept to activity-based passenger models.

G- Logistics/ supply chain model combining features of logistics chain models and tour-based models to analyze urban goods movement flows.

Table 1. Comparison of Freight Modeling Techniques and Framework

Model	Strength	Limitations	Major model components
A- Link-based factoring model	• Low complexity • Low cost • Multi-variable • Corridor/mode specific	• Not suitable for analyzing complicated scenarios • Unable to provide any forecast on locations without existing counts • Developing accurate growth factors requires a separate economic model • No supply/demand relationship • Not network based	• Truck count database • A set of growth factors
B- Origin-destination (O-D) factoring model	• Low complexity • Relatively low cost • Available national data • Easily adaptable to different scale • Multi-modal commodity flows	• Observed disaggregate data is proprietary • Estimated disaggregate data is expensive • It is not directly integrated with economic census	• Sample O-D surveys or GPS OD Data • Expanded Truck O-D table (developed using origin-destination matrix estimation (ODME) process) • Network assignment module
C- 3-step truck models / D- 4-step commodity models	• Predictive model • Multi-modal commodity flows • Able to do detailed scenario analysis	• Extensive data collection requirement or need to purchase expensive data • Takes relatively long time to develop	• Trip generation • Trip distribution (mode split) • Trip assignment
E- Economic activity models	• Economic and land use data are integrated with 3 or 4 step model • Available public data at local level as well as national	• Linear relationship between economic activity and freight flows is not always true	• Land use model • All components of 4-step models • Tonnage/ $ to truck conversion module
F- Tour-based model	• Involved detail data about raw materials and finished goods • Capture movements of vehicles and decisions of carriers more realistically • More accurately forecast truck traffic at local level	• Significant data requirements such as truckload data, intermodal facilities, firm shipment sizes and distribution and truck activity diaries • Takes very long time to develop and validate	• All components of 4-step • Modules to generate components of a tour
G- Logistics/supply chain model	• Very sensitive to economics of various industries for policy making • Similar to Hybrid models	• Significant amount of data is required from various data sources, which might be difficult to acquire	• Complex economic model including domestic and international all component of table

The models discussed in Table 1 have different capabilities and each can be helpful in various types of studies. However, there is no single tool that can answer all questions. Table 2 shows the types of analysis needs that were requested by the practitioners. Some of these analyses can be directly accomplished with the model (Primary) and some require post-processing the results of the model and further research to identify the relationship between the primary result of the model and desired analysis needs (Secondary data).

Table 2. Comparison of potential Analysis with Each Model Category

Needs	Type of Freight / Truck model						
	A	B	C	D	E	F	G
Regional transportation planning	-	P	P	P	P	P	P
Project prioritization	P	S	P	P	P	P	P
Mode shift analysis	-	S	-	P	P	P	P
Pavement management	P	S	P	P	P	P	P
Policy evaluation/ economic studies	-	-	-	-	-	P	P
Needs analysis	P	S	P	P	P	P	P
Commodity flow analysis	-	P	-	P	P	P	P
Rail planning	-	S	-	P	P	P	P
Trade corridor planning	-	-	-	-	-	S	-
Operations, safety, security, truck size and weight issues	-	-	-	-	S	S	P
Project development or design needs	P	S	S	S	S	P	P
Terminal access planning	-	S	-	S	P	P	P
Truck flow analysis and forecasting	-	S	P	P	P	P	P
Performance measurement/ program evaluation	-	-	S	S	S	S	S
Bottleneck analysis	-	-	S	S	S	S	S

*P: Primary, S: Secondary
Source: adapted partially from Chow et al., 2010

As shown in the table, each category of model may not answer all types of analysis. It is crucial to understand what the needs of the MPOs in the Valley are and what the right tool to use is.

In this report, we provide the pros and cons of each modeling technique based on various criteria. A survey was conducted among modelers and planners in the Valley to clearly identify their needs and concerns about the existing Valley truck model. Considering this information, we recommend a future development framework for an upgraded Valley truck model. The objective is to make best use of available information and develop a model with minimum maintenance cost.

As a part of training materials, three sample scenarios are included in the attachments of this report. These scenarios are developed for training purposes to explain various aspects of freight modeling.

FREIGHT MODELING NEEDS ANALYSIS

As part of "San Joaquin Valley Goods Movement Sustainable Implementation Plan", we hosted three online webinars for a Valley freight user group. This group includes modelers and planners active in freight planning in Valley. Participants of the webinar were asked to respond to a survey to evaluate applications and requirements of a truck model for the San Joaquin Valley. The responses to this survey and discussions during the webinars helped the consultant team to provide a framework and road map for truck modeling in the Valley that address the needs of all MPOs. Eleven people participated in the online survey. The survey questions are provided below.

FREIGHT MODELING USER GROUP SURVEY

1. Have you used San Joaquin truck model before? If yes, for what purpose?

2. Are you familiar with San Joaquin Valley Model Improvement Program (SJV MIP)? Have you used the passenger model before? If yes, for what purpose?

3. Which of the following information will improve your planning process:
   - Commodity flow information
   - FHWA axle-based truck classification
   - ARB weight truck classification
   - Empty truck movements
   - Non- freight or service trucks
   - Information about trucking activities in urban areas
   - Other

4. What kinds of analysis are you interested to do using a truck model?
   a. Truck route choice (Select link analysis)
   b. Origin destination traffic patterns
   c. Internal Valley trips (I-I) vs trip from/to other parts of the state to/from the Valley (IX-XI)
   d. Fuel consumption
   e. Speed
   f. Other

5. What types of policies or scenarios are you expected to conduct with a freight model?
   a. Capital investment (add truck lane, trip generator)
   b. Truck tolls
   c. Mode share (truck/rail)

   d. Green trucks
   e. Size and weight limits
   f. Diesel tax
   g. Other
6. What are your preferred freight related performance measures?
   a. Truck volume/percent/PCE
   b. Truck VMT by area type
   c. Truck VMT by speed bin
   d. Other metrics

SUMMARY OF THE SURVEY RESULTS

The Valleywide truck model has not been used by any of the respondents for various reasons:

- No need to use it
- It is not easy to use / don't know how to use it / the documentation is not adequate
- It is out of date
- The model is not well validated
- It does not provide the level of detail and information needed

The following analyses are identified as current needs or near-future potential needs:

- Corridor analysis
- Truck route choice sensitivity analysis for corridor improvement projects
- Truck traffic pattern
- Regional analysis
- Through trips vs. local trips
- Short-haul vs. long-haul trips share
- Origin-Destination patterns
- User classification (by type of truck, by commodity group, by trip classification)
- Truck VMT / trip length
- Mode share
- Emissions
- Demand for truck stop / loading and unloading zones
- Safety improvement projects evaluation
- Seasonality of different agriculture activities. (For example, harvesting produce vs. packaging require different types of trucks and labor.)

The recommended framework must consider the following requirements for the truck model:

- Easy to use (user-friendly)
- Include well-documented user guide and training material
- Low maintenance cost and regularly updated

- Seamlessly integrated with passenger model
- Calibrated well to major arterials
- Sensitive route/mode choice component
- Trip rates based on detailed industry categories
- Include trucking activities in urban areas
- Provide FHWA axle-based truck classification
- Compatible with ARB weight-based truck classification
- Include empty truck movements
- Identify trucks by purpose (agriculture trucks vs. others)
- Has detailed zone system, compatible with passenger model
- Include truck routes, truck-prohibited routes, primary connectors, and intermodal facilities
- Has built-in post processors to calculate VMT, trip length, greenhouse gas (GHG), emissions
- Include maintenance and pavement impact analysis
- Account for seasonality of agriculture products

PERFORMANCE MEASURES

The following potential list of performance measures was developed during the San Joaquin Valley freight user group workshop. The objective was to evaluate the performance of the model under each scenario. Some of these metrics require information not currently built into the model (such as value of shipments) or the model is not directly sensitive to it (such as roadway capacity), and those will be recommended for future enhancement of the model. For each scenario, relevant performance measures will be estimated and compared to the baseline values.

- Efficiency
  - Empty truck flows
  - Logistic cost (by industry)
  - Economic analysis
  - Commodity flow distribution by mode (truck, rail, air, multi-modal, pipeline) at 100+ FAZs
  - Economic indicators: employment, population, GDP, fuel price
  - Toll (in future, to evaluate feasibility of truck only lane)
  - Connectivity and accessibility
  - First and last mile urban/rural freight corridors evaluation
  - Green supply chain support (warehousing, intermodal facility, alternative fuel fleet, etc.)
- Highway Traffic Congestion
  - Annual Average Daily Truck Traffic (AADTT)
  - Seasonal AADTT / peak hour volumes
  - Classified freight truck VMT (by truck class, commodity group, empty/loaded, air basin, county)
  - Multi-modal Operation
  - Railway share

    - Seaport-related truck traffic
    - Comparative Measures:
        - Freight truck VHT
        - GHG
        - Emission
- Impact of advanced technologies
    - Truck platooning
    - Drone deliveries
    - Urban distribution centers (more small trucks, more local distribution centers)
    - Autonomous trucks (longer hours of service)
- Economic impact metrics
    - Domestic vs. import/export share
    - Regional goods movement trends (by mode, by truck class, by tonnage, using average value of shipment at each region)
- Multimodal impact metrics (for O&Ds with access to rail, the ratio of rail/multimodal tonnage to truck tonnage)
- VMT/VHT related metrics:
    - By origin zone
    - By industry (commodity)
    - By truck size
    - With/without through trips
    - By speed bin
    - By value of shipment
    - By trip length
- Link level metrics
    - Truck traffic volumes (by type)
    - Speed profile (by type)
    - Volume/Capacity Ratio
    - LOS: HCS methodology for freeways and major arterials
    - Delay: difference between free flow speed and congested speed
- Pavement impact/maintenance
- Safety index: ratio of number of Killed or Severely Injured (KSI) collisions over volume (truck volume)

REVIEW OF COMMERCIAL VEHICLE MODELING TECHNIQUES AND APPLICATIONS

The commercial vehicle models that are currently being used by several states and MPOs can be classified into:

- Link-based factoring
- Origin-destination (O-D) factoring
- Freight carrying truck models
- 4-step commodity models
- Economic activity models
- Hybrid models

Beside the above models, research programs throughout North America and Europe are currently developing a more advanced generation of freight models. Two techniques in particular are receiving widespread interest:

- Logistics/supply chain models
- Tour-based models

The logistics/supply chain models borrow techniques from industrial supply chain planning in an effort to track goods as they move along the supply chain from producer to consumer. The tour-based models focus on the trip chain characteristics of intra-metropolitan trucks. Examples of these model types are presented below.

LINK-BASED GROWTH FACTORING MODEL

This simple and quick method permits existing data to be applied rapidly, and is usually intended for short-term forecasts of truck volumes for a selected set of links on the roadway network. Many assumptions are needed to make these methods work, and the range of applicability is limited. The two steps of link-based factoring technique are presented here:

Step 1 - Observed Link Traffic Volumes: develop an existing truck volume database for desired facilities on a modal network link or at a freight-related terminal.

Step 2 - Growth Factors: develop factors to estimate changes in truck volumes due to changes in transportation service on the facility or on an alternative facility of the same or different mode.

Example: to develop future year truck forecast volumes, observed truck counts on a specific highway are increased by a certain percent per year. The percent value may be derived from historical truck volume growth or based on another surrogate variable such as employment or economic growth.

The Quick Response Freight Manual – Part I [1996], developed for the Federal Highway Administration (FHWA), describes methods of applying growth factors to traffic volumes that are applicable to urban highways. The inability of this method to analyze complicated scenarios and evaluate projects' impacts challenges MPOs and States to aim for more sophisticated models; however, its simplicity and ease of use makes it an attractive option for aggregate and sketch-level analyses.

ORIGIN-DESTINATION GROWTH FACTORING MODEL

This method forecasts truck flows by factoring a base year truck origin-destination table of truck flows and assigning the new truck O-D tables to the highway network. It differs from the link-based method in that truck volumes are not directly observed, but produced by assigning a truck O-D table to a highway network.

A variation on this approach is the factoring of commodity flow tables that provide tonnage flows by commodity between origins and destinations, splitting these flows among the available modes (using a mode choice model or fixed modal shares from the base year), and converting the truck flows to truck trips. The commodity O-D factoring approach is frequently used for statewide freight models, which generally focus on long-haul freight movement. Long-haul movement is well characterized in commodity flow datasets such as the Commodity Flow Survey and the IHS Global Insight TRANSEARCH database.

With increasing availability and affordability of GPS truck trajectory data with large geographic coverage and substantial sample size (such as from the American Trucking Research Institute (ATRI) and StreetLight), this method is becoming very popular in estimation of existing truck O-D tables. Three steps are required for the O-D factoring forecast method:

Step 1 - A base year O-D trip table for trucks (or a commodity flow table)

Base year O-D truck trip tables can be estimated in a variety of ways, depending on the availability of data. One approach that has been used widely is the origin-destination matrix estimation (ODME) process. This method utilizes observed truck counts and partial O-D data (usually from O-D surveys or GPS trajectories) to estimate a truck trip table. Non-linear programming techniques are used to estimate a trip table that, when assigned to the network, minimizes the difference between predicted and observed truck volumes.

The partial O-D data and best judgment estimates for the unknown O-D information are used to construct a "seed" table. The non-linear programming process then adjusts the trip table to obtain the best fit with the truck count data. The base year table produced from the ODME method can then be factored to a forecast year using the methods described previously. The ODME process is available as a standard module in CUBE Analyst[1] and TransCAD travel demand model packages.

Step 2 - Growth factors for the O-D table

Growth factors can be based on economic output, employment, or other growth indicators at the zonal level. The growth rates are often developed by using simple economic models. They are then applied to the base year O-D truck trip tables using iterative proportional fitting techniques to balance production and attraction growth rates. The iterative proportional fitting technique commonly used in transportation planning is known as Fratar factoring. CUBE and TransCAD have standard modules to implement this technique.

Step 3 - Assign the truck table to the highway network

There are a range of well-established methods in transportation network literature discussing assigning truck tables to the highway network. Many of these methods are already implemented in CUBE and TransCAD. The choice of the network assignment method depends of the availability of other data and purpose of the model. It is not limited by the O-D factoring models.

3-STEP TRUCK MODELS

Truck trips can be classified as two major purposes, freight and non-freight truck trips. Similarly, there are two classes of 3-step truck models:

- Freight-only truck models
- All commercial truck models

Freight truck models develop highway freight truck flows by assigning an O-D table of freight truck flows to a highway network. The O-D truck table is produced by applying truck trip generation and distribution steps to existing and forecast employment and/or other variables of economic activity for analysis zones. This method differs from O-D factoring in that the O-D table is estimated directly using trip generation rates/equations and trip distribution models at the traffic analysis zone (TAZ) level. The mode choice step

[1] It is also possible in standard Voyager. It requires to program it as iterative matrix adjustment.

is unnecessary since truck trips are estimated directly and there is no need for the consideration of other possible modes for moving freight. The components required for this modeling technique include existing and forecast zonal employment data, methods to generate zonal freight productions and attractions by using freight truck trip generation rates, methods to generate truck O-D flows by applying trip distribution procedures to truck productions and attractions and methods to assign the O-D freight truck flows to a highway network.

Freight truck models usually attempt to account for shipment of goods, including local delivery. Because these models are focused exclusively on the truck mode, they cannot analyze shifts between modes. Empty trucks are usually included in these models. In a simple form it is estimated as a fraction of the inverse of the final freight O-D table for each O-D pair. These fractions usually depend on the distance between the origin and destination, where it is higher for close O-D pairs and lower for further O-D pairs.

Freight truck models are powerful tools in analyzing the impacts of economic growth and agricultural, manufacturing and industrial shifts on regional goods movement. However, since freight trucks are only a fraction of total truck traffic on a highway network, comparison of a model's forecast truck traffic volumes with truck counts is not an apple to apple comparison. As a result, validation of highway network assignment volumes for these models is not trivial and requires local knowledge about each screenline or validation point and reasonable assumptions for qualitative assessment.

The California Statewide Freight Model 2.0 is a freight truck model. Truck models are usually part of a comprehensive model that forecasts both passenger and freight movement and consequently will often use a simultaneous assignment of truck trips with auto trips.

Comprehensive commercial truck models attempt to account for all truck traffic in a network. The SCAG Heavy Duty Truck Model is an example of this category. These models may not differentiate between different truck purposes but usually include multiple aggregate truck classes by axle or by weight. For example, in the SCAG heavy duty truck model, there are three classes of heavy duty trucks: light-heavy (8,500 to 14,000 lbs. gross vehicle weight (GVW); medium-heavy (14,001 to 33,000 lbs. GVW); and heavy-heavy (>33,000 lbs. GVW). The result of the network assignment module of these models can be validated using traditional methods; comparing the model forecasted volumes with the truck counts for each vehicle class.

The major steps in 3-step truck models are summarized here:

Step 1 - Trip generation

Trip generation estimates the number of trips either produced in each zone or attracted to each zone and is usually a function of socioeconomic characteristics of the zone (employment by industry, population, or number of households). Trip generation is accomplished using truck production and attraction equations whose coefficients are estimated based on local surveys, or by using parameters borrowed from other sources such as the Quick Response Freight Manual.

Where large sample of GPS truck O-D data and adequate truck count data are available, it is possible to use the ODME method (explained in the O-D growth factoring method) to estimate the complete truck O-D table. The marginal of this table (total production and total attraction) can be used as "observed" truck trip generation values. A linear regression model (or other models) can be used to relate land use characteristics of each TAZ (such as number of employment) to number of truck trips started/destined at each TAZ.

Step 2 - Trip distribution

Trip distribution determines the connection between trip origins and trip destinations. Trip distribution is generally accomplished using a gravity model similar to that used in a passenger model. In the gravity model, the number of trips that travel between one zone and another is a function of the number of trip attractions in the destination zone and is inversely proportional to a factor measuring the impedance between the two zones. The gravity model is usually related to the travel time between two zones, i.e., the longer it takes to get from one zone to another, the less attractive trips to that destination zone becomes. Parameters in the gravity model can be developed from local surveys, GPS trajectory data or borrowed from other sources such as the Quick Response Freight Manual.

Step 3 - Traffic assignment

The route that trucks use to get from origin to destination is a function of network characteristics, taking into account traffic conditions on each route. Network assignment of the truck trips is usually based on a multi-class equilibrium highway assignment that includes passenger cars; in other words, the model looks for the path with lowest cost for all trips simultaneously. The cost function can be a composite function of direct travel time, terminal time and tolls (if any). Freight truck models can take into account the different classes of trucks and their impact on congestion compared to automobiles (large trucks cause more congestion because they occupy more space than autos). This is usually done by converting truck trips into passenger car equivalents (PCE) with factors that differ depending on the size of the truck (i.e., different truck classes in the model may use different PCE factors). In addition, the networks can be coded so that any specific link can either allow only truck trips or can exclude the use of truck trips.

4-STEP COMMODITY FLOW MODELS

Commodity models can analyze the impact of changes in employment, trip patterns, and network infrastructure. The process of the 4-step commodity flow model is similar to the 3-step truck model with an extra step of mode choice or mode split before network assignment (Figure 1).

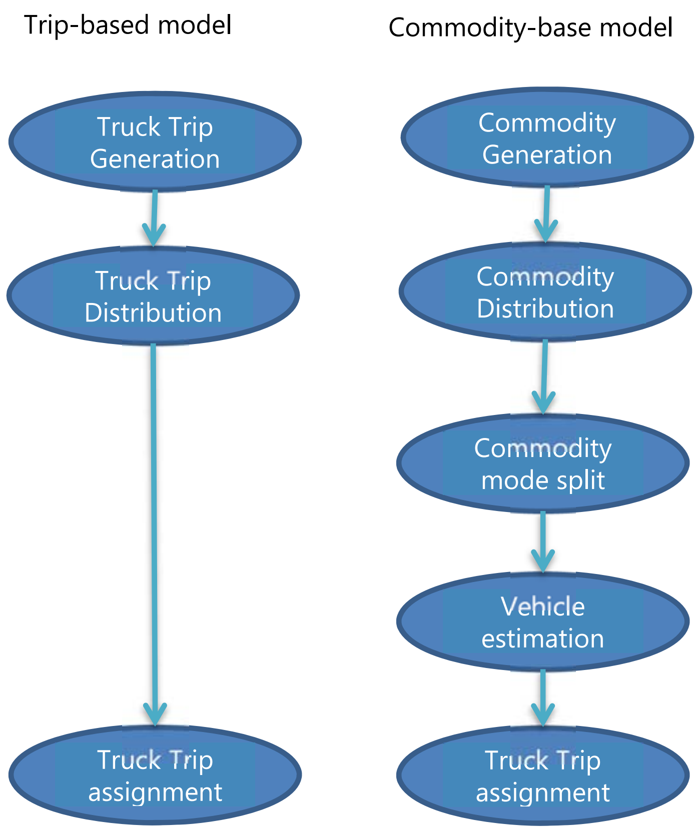


Figure 1. Trip Based and Commodity Based Truck Model

Step 1 - Trip generation

The commodity-based "trip" generation model actually estimates the tonnage flows between origins and destinations. These flows are converted to vehicle trips after the mode choice step in the process. The trip generation models include a set of annual or daily commodity tonnage generation rates or equations by commodity group that estimate annual or daily flows as functions of TAZ or county population and disaggregated employment data. Base year commodity flow data at the zonal level are used to estimate the trip rates or trip generation equations.

Step 2 - Trip distribution

The O-D tables for these flows are typically estimated using gravity models similar to the trip distribution step in 4-step passenger models. Trip distribution models are estimated separately for each commodity group. The unit of flow in the O-D table is typically tons shipped. The distribution of freight is to an aggregate system of zones, recognizing the large average trip lengths in this class of models.

Step 3 - Mode choice/mode split

In a 4-step passenger model, the discrete mode choice model is usually a logit model calibrated based on data from household travel survey, transit ridership survey, vehicle ownership and vehicle occupancy. The output of this model is the proportion of travelers which would use each of the available modes of transport (e.g., 70% by car and 30% by public transport). This is the most complex and data-intensive step of the four steps in passenger travel demand modeling. In freight modeling this step is even more challenging due to the complexity of the system and participation of multiple decision makers with conflicting goals in the process (e.g., shipper, third party logistics, and motor or rail carrier).

Where the schedule and budget is constrained, it is common to simplify the mode choice module with a mode split module. In this case the mode split step simply assumes that the base year mode share of each commodity group flow stays the same in the future. This is effectively assuming that the most important factor determining mode choice is the type of commodity with certain commodities having a preference for using a particular mode. This type of simple mode choice can also take into account the distance of the trip for very long hauls, with modes like rail being used more intensively for long trips. This module is a necessary component because O-D patterns are developed for a particular set of commodity groups rather than only for trucks.

Step 3-1 - Annual tonnage to daily truck conversion

The conversion of commodity truck tonnage to daily freight truck trips uses the application of payload factors (average weight of cargo carried per vehicle load). Payload factors can be estimated on a commodity-by-commodity basis using locally collected survey data (e.g., roadside intercept surveys) or national surveys (e.g., the U.S. Census Bureau Vehicle Inventory and Use Survey (VIUS)). It should be noted that the national VIUS was discontinued after 2002. There is discussion at U.S. DOT about the possibility of developing a new national VIUS. In the meantime, Caltrans is in the process of developing a state level VIUS that should be able to provide payload factors when it is completed in 2018.

Weigh in motion (WIM) data can also be used to estimate the average payload of trucks by axle configuration.

Step 4 - Traffic assignment

The structure of the 4-step commodity flow model is similar to the 4-step passenger model. Both models require the development of a network and zone structure. However, the percentage of long-haul freight trips in an urban area is larger than the percentage of long-haul passenger trips; therefore, a primary highway network external to the region is usually appended to a local passenger network to allow for assignment of these long-haul freight trips. The assignment of freight truck will typically use either a freight truck only or multi-class assignment model.

ECONOMIC ACTIVITY MODELS

An economic activity model includes an economic or land use model as a step before the traditional four steps. Economic activity models are the freight equivalent of the integrated land use transportation models used in the passenger travel behavior analysis. They require specific data concerning the availability of land and the rules governing the development and location of certain industries, and an understanding of the interdependencies between industries.

Economic activity models estimate the flows of commodities between economic sectors in each zone. They assume that the zonal employment or economic activity is not directly supplied to the model but is created by applying an economic or land use model. A spatial input-output (I-O) model is a common technique used for economic activity models. The spatial I-O model distributes household and economic activity across zones, uses links and nodes of a transportation network to connect the zones and model the transportation system, and then calculates transportation flows on the network. It uses a land use component to generate and distribute trips and a transportation component to generate mode split and network assignments. There are two main components in the economic activity models:

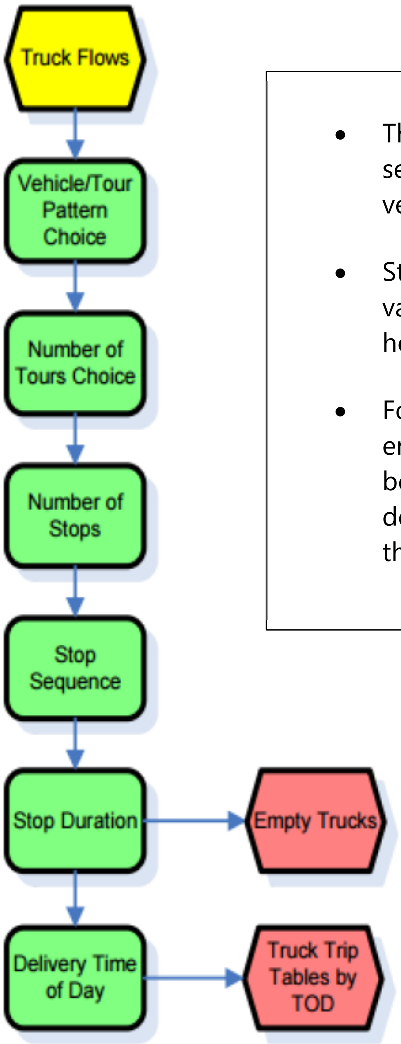
1) Economy and land use model
2) Transportation model

These two components of the model inform each other, resulting in a dynamic model. The model uses an I-O structure of the economy to simulate economic transactions that generate transportation activity. A spatial I-O model identifies economic relationships between industries and between industries and households, accounting for the geographic or spatial relationships associated with the economic relationships (origins and destinations of the economic flows). In future years, the spatial allocation of economic activity, and thus trip flows, is influenced by the attributes of the transport network in previous years. Thus, the model is dynamic with respect to land use and transportation.

An economic activity model differs from the 4-step commodity class of models in that it uses an economic or land use model to forecast zonal employment or economic activity prior to the trip generation step. The complexity and amount of data and effort required to calibrate and validate these models makes it less popular among States and MPOs. Therefore, very few functional economic activity models have been developed. The freight component of the Oregon Department of Transportation's statewide travel demand model is an example of an economic activity model.

TOUR-BASED MODELS

The basic concept behind truck tour-based models is consistent with activity-based passenger models. These models focus on the tour characteristics of truck trips. For urban truck movements, a tour-based modeling approach can replicate the real behavior of trucking activities more closely. In a tour-based modeling framework, the activity of vehicles is tracked. The components of such a model will operate at the vehicle level. Therefore, they will only generate estimates of a single mode. Vehicles are associated with establishments, and vehicle activity is seen as a function of the type of activity that occurs at that establishment. Tour-based truck models usually have a synthetic population of business establishments, which is developed from aggregate data. These are used to estimate the number of tours generated for a particular commercial activity. However, similar to passenger models, tour-based models also operate with zones, so the estimated activity will be aggregated for all of the establishments in a zone. Figure 2 shows the major steps of a simple truck tour-based model.



- The business establishments (retail establishments, service businesses, or any other type of commercial vehicle operation) are the generators of the tours.
- Stops on the tours are generated based on traditional variables used in trip generation (population, households, employment by business sector).
- For each vehicle tour, a series of choice models are employed to determine: the type of vehicle that will be used, the purpose of each stop (goods pickup or delivery, service, return to home), and the location of the next stop.

Source: adopted from Outwater et al. 2012

Figure 2. Truck Tour-Based Model Process

A truck tour-based model has several choice model components estimated from travel diary data. They are logit choice models that use variables related to what has happened previously on the tour, the attractiveness of zones that could include the next stop on the tour (measured in terms of the number of trip attractions estimated for the zone), and the location of the stops relative to home base (taking into account travel times from zone to zone).

The statewide freight model for Wisconsin DOT and a mega-regional freight model for the Phoenix MPO, Maricopa Association of Governments (MAG) have recently updated their tour-based models (Figure 3). These models are able to:

- Address the changing conditions in freight supply and demand in the respective regions. Freight supply is provided by infrastructure and carriers or other operators, while demand for freight transportation is generated by individual businesses that are trading goods with one another.
- Capture transportation decisions, such as mode choice and the use of logistical handling facilities (e.g., intermodal yards) for individual firms. In doing so, the model adopts an intuitive, agent-based approach for understanding the underlying economics that motivate business decisions. These individual business decisions are then effectively aggregated by the model into trip tables that can be used for a variety of highly insightful analyses.
- Simulate freight network performance at a detailed level in the anticipated microscale model. This component of the model can simulate individual vehicle movements, allowing the respective agencies to analyze impacts of new infrastructure projects at a highly detailed level.

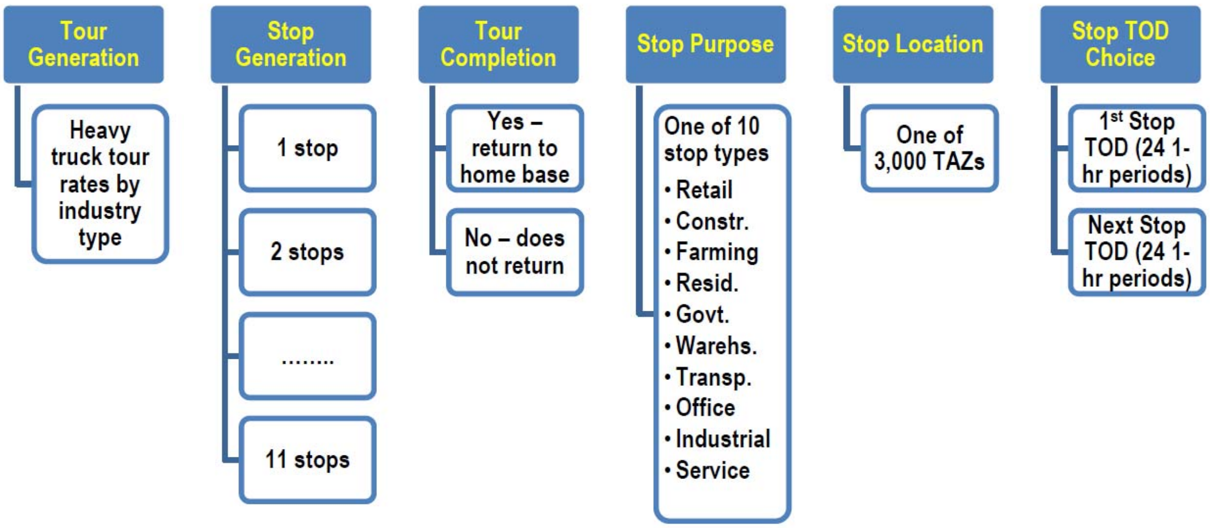


Figure 3. MAG Tour-Based Truck Model Structure

HYBRID MODELS

Several hybrids models that blend commodity flow modeling techniques with truck modeling techniques have been developed over the past decade. Generally Hybrid models try to include all commercial trucks. Commodity flow databases tend to be relatively accurate for inter-county flows, but undercount intra-county flows because commodity flow databases rely in part on economic input-output data that ultimately are based on financial transactions between producers and consumers of goods. However, in an urban area, many truck trips are not easily traced to such transactions. Moves from warehouses and distribution centers, repositioning of fleets, drayage moves, parcel delivery, and the like are generally short-distance trips in which there may not be an economic exchange of goods from one party to another. To better understand this challenge different truck purposes are explained in the following section.

TRUCK PURPOSES

Similar to passenger models, there are different trip purposes in truck models. It is important to understand these purposes to define the scope and scale of a suitable model for the San Joaquin Valley. Trip purposes are usually defined based on available reliable data. In passenger models, major trip purposes are home-based and non-home-base trips; each major trip purpose can be further disaggregated to more specific purposes such as home-based work, home-based school, and home-based shopping trips. Similarly, truck trips purposes can be categorized into two major categories: "freight truck trips" and "non-freight truck trips." The definition of "freight trips" can be nebulous and can vary based on the assumptions of the data collection process. Here is an example classification:

Freight Truck Trips:

- Long- and short-haul trips to ship commodities in return for a shipping fee. Freight trips can derived from Commodity Flow Survey (CFS)[2] or Freight Analysis Framework (FAF)[3] data or Transearch data[4].

Non-Freight Truck Trips

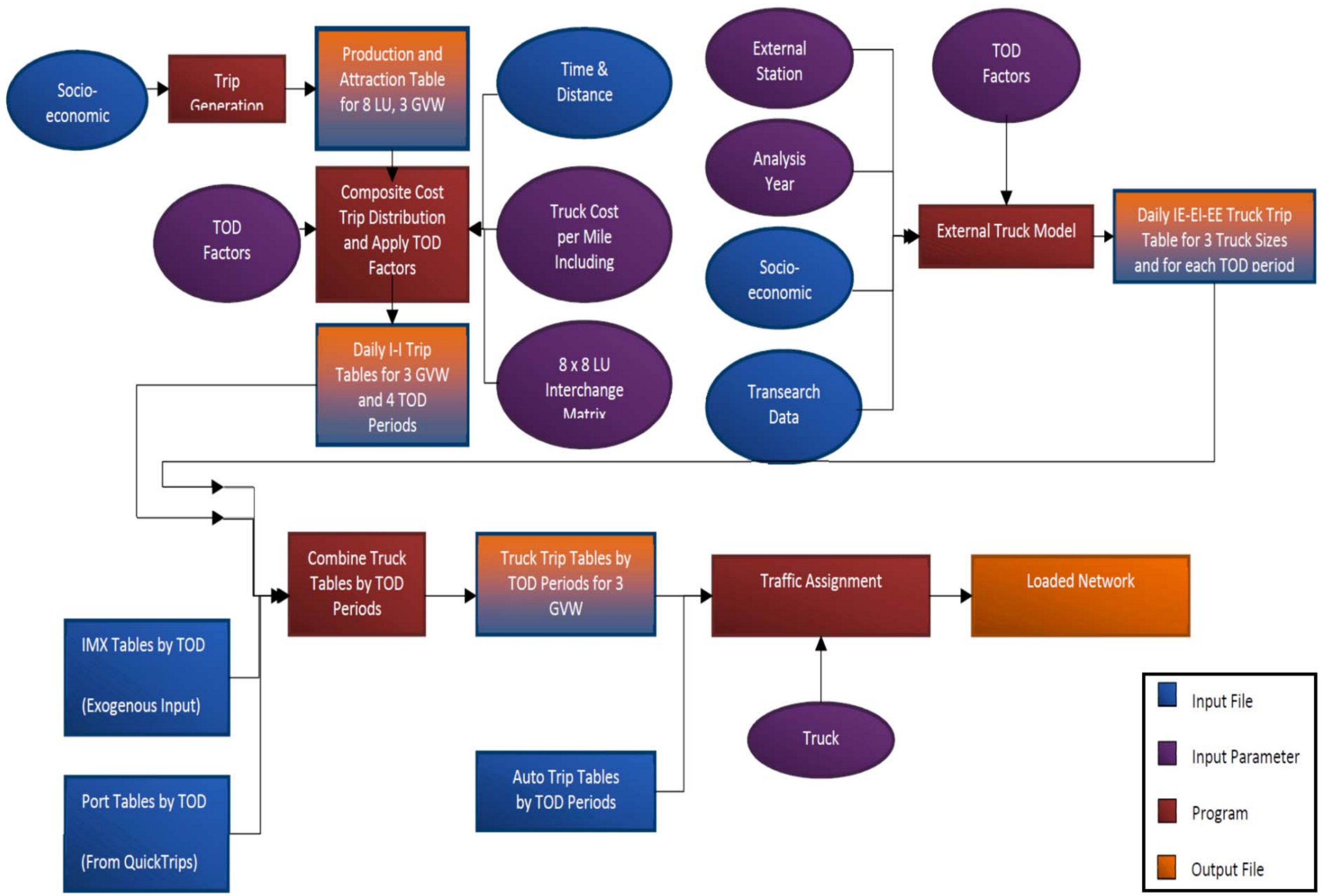
Many of the cargo haulage are not included in "freight truck" category. To account for all commercial trucks, they will be accounted for as non-freight. Some examples are presented in Figure 8.

- Empty trips: unavoidable, non-profit-generating long- and short-haul trips that reconcile imbalanced production and consumption patterns.
- Local delivery trips: short-haul trips made by small- or medium-sized trucks for the following trip purposes:
    - Truck trips from distribution centers to local retail stores
    - Truck trips between retail stores or business
    - Mail delivery services to businesses and households: FedEx, UPS, USPS, Amazon
- Service trips: usually short-haul trips that might not deliver any shipments but may carry cargo or tools to provide services. These include various truck sizes and types, such as:
    - Municipal/waste collection trucks
    - Utility/street sweeping trucks
    - Construction/concrete trucks
    - gardening, landscaping

Figure 4. Examples of Non-Freight Trucks

Figure 5 shows the structure of SCAG's Heavy Duty Truck Model. This is a hybrid Heavy-Duty Truck (HDT) model based on commodity flow and truck surveys. In hybrid models, the undercounting of shorter distance trips is compensated by local truck trips that are generated based on local employment and economic factors using trip generation rates. The trip rates were derived from a variety of sources for the SCAG region that included trip diary surveys, establishment surveys and truck GPS data from multiple third-party vendors. These trip rates are applied at the zone level to generate truck trips, while truck trip distribution uses methods such as gravity models. The trip rates are calibrated so that the truck traffic volumes that are generated from the combined commodity flow and locally generated truck trips match those from available truck counts. Several categories of trips are identified, including commodity flow trips versus locally generated trips, external versus internal truck trips and long-haul versus local truck trips.

Figure 5. SCAG HDT Model Structure



(TOD = Time-of-Day, circles are the observed data. Squares are the models estimates)

Source: SCAG HDT Model Development Report, 2012

LOGISTICS/SUPPLY CHAIN MODELS

Supply chain models combine features of logistics chain models and tour-based models to analyze urban goods movement flows. Because of the complexity of these models and difficulty of collecting proprietary data, supply chain models are more popular among researchers to explain relationships between components of supply chains. The few examples we found in the literature were not updated since they were developed 10-15 years ago and not used by practitioners regularly. Generally, this category of models defines a set of activity types, which when linked together may describe either a logistical chain or a set of stops on a vehicle tour (or in some cases, a combination of both). These chain models work best when the goods transported move in large lot shipments, with little mixing of the commodities, often in single shipment transport loads, or in multiple shipment loads delivered in a "descending load, return empty" pattern. Additionally, the logistics chains should be relatively simple with few choices of distribution channel options.

One of the early models in this category is a conceptual model developed for Los Angeles County, developed in 2005 but never fully implemented. This model has three layers for evaluating freight movements going to, from, and through the Los Angeles region. The layers are:

1. Economic Layer, which captures the macroeconomic factors that influence freight demand and commodity supply/demand relationships;

2. Logistics Layer, which captures the supply chain and logistics decisions that firms make in response to supply and demand conditions (including choice of distribution channels, modes, etc.); and

3. Transport Layer, which captures the transportation system costs and performance that are linked to logistics decisions, and ultimately determine the traffic/vehicle flows on multimodal networks.

Although the underlying behaviors in logistics chain modeling and tour-based modeling are different, the basic structure of the models is similar, which makes their integration very easy, as shown in Figure 6. Each type of model represents an activity chain. In each step of the chain, choices are made concerning what activity will occur next, the type of facility to be used and the location of the facility.

These choices lead to other choices about the modes, or types of equipment to be used and the loads the equipment will carry. These choices will be modeled using a discrete choice simulation model incorporating various forms of logit and nested logit choice models. Each choice in the logit model is a function of the location of attractions in the chain, the magnitude of these attractions, the characteristics of each facility or stop option, and previous choices made in the activity chain. Although the underlying behavior of each type of model has noticeable differences, the basic mathematical structure is similar, making the formulation of an integrated modeling approach mathematically easier to accomplish. The common mathematical structure of the two models also suggests the possibility of using common software for the integrated model.

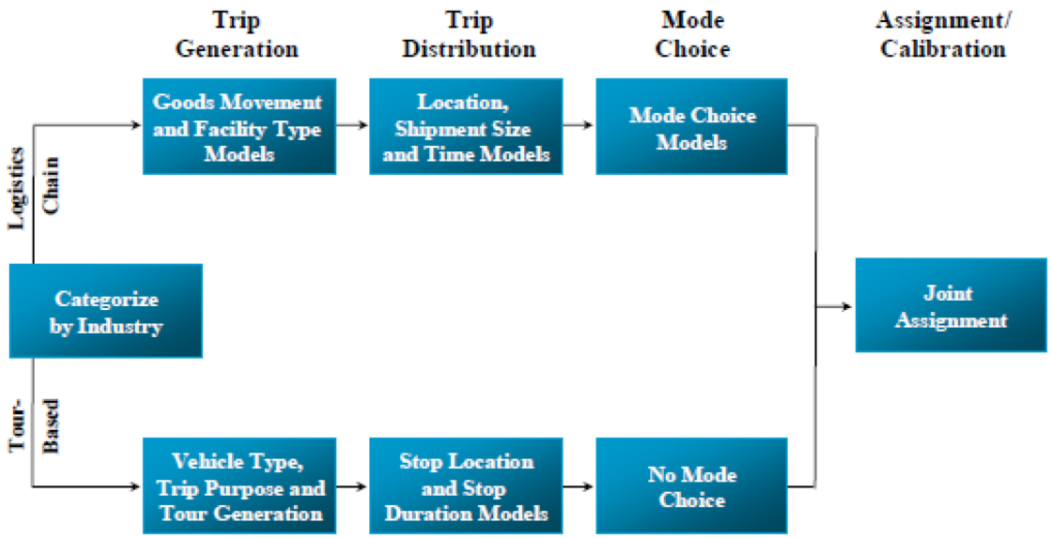


Figure 6. Overview of LA County Integrated Modeling Framework

Another example is the GoodTrip Model supply chain model developed by Delft University of Technology for the Netherlands in 2000. This model combines features of logistics chain models and tour-based models to analyze urban goods movement flows. The model defines a set of activity types, which when linked together may describe either a logistical chain or a set of stops on a vehicle tour (or in some cases, a combination of both). Activity types include:

- Consumers
- Supermarkets
- Teleshop
- Hypermarkets
- Urban distribution centers
- Factories

The model starts its calculations at the consumption end of the chain and estimates the demand for goods by goods type (analogous to commodity) for each zone in the model. The share of this demand allocated to each of the activity types in each zone is also estimated based on models developed from survey data. The model then uses information about the spatial and functional relationships of each of the activity types and probabilities to estimate flows by activity type and zone. The goods flows are then assigned to vehicle tours for each origin-destination pair. The origin's activity type determines the transport mode, vehicle capacity, vehicle loading factor, and number of stops per tour. This conversion of goods flows to vehicle tours establishes the trip table for assignment to a network. This modeling approach has a rich urban focus with an ability to analyze how changes in logistics organization affect vehicle traffic.

SUMMARY OF PROS AND CONS OF MODELING APPROACHES

Each of the modeling techniques described in the previous sections has strengths and weaknesses as described in Table 1. In Table 3 we summarized the common applications for each of the modeling categories. The commodity flow models have the advantage of being based on extensive and readily available multimodal freight flow and economic activity data. On the other hand, many local truck moves, including trips from warehouses and distribution centers, fleet repositioning, empty return trips and truck drayage moves, as well as service, utility, and construction trucks, are not accounted for in these models.

Many of these missed truck trips are short trips within urban areas. Therefore, truck models based exclusively on commodity flow data tend to underestimate truck trips in the urban area. In addition, the commodity flow data are generally not available at the TAZ level and techniques of questionable accuracy must be used to disaggregate county-level data.

Models built exclusively from truck trip generation and attraction rates based on local economic activity have the advantage of being tailored to the economic activity data of the study area. Truck trip generation rates can be estimated from local data that include all truck moves, not simply moves based on commodity flows. These models can be made more responsive to changes in local economic activity and population relative to truck models based on commodity flow data. However, truck models based on locally generated truck trips do not incorporate goods movement factors for external regions. Therefore, external and through truck trips are not well modeled. Additionally, changes in external regions over time cannot easily be incorporated into truck model forecasts. The behavioral basis of these models is crude, they cannot reflect changes in the structure of truck operations over time, and they do not accurately account for the trip chain characteristics of many urban truck trips. Finally, the data required to estimate accurate trip generation and distribution models given the variety of truck trip types are very extensive. Collecting sufficient data of this type from private businesses has proven to be very difficult in past studies.

Table 3. Summary of Modeling methodologies and their applications

Model	Major model components	Model Application
A- Link-based factoring model	• Truck count database • A set of growth factors (GDP or population growth rate)	• Trend Analysis • High-level future forecast scenarios

B- Origin-destination (O-D) factoring model	• Sample O-D surveys or GPS OD Data • Expanded Truck O-D table (developed using origin-destination matrix estimation (ODME) process	• Include applications listed under A • Comparison of relative flows between O-D pairs
C- 3-step truck models / D- 4-step commodity models	• Trip generation • Trip distribution (mode split) • Trip Assignment	• Include applications listed under A and B • Select link/zone analysis • Network improvement projects evaluation • Network pricing (Tolls) strategies • Congestion/ Delay/ travel time reliability / capacity/ pavement Impact analysis • Energy consumption and emission analysis • Truck weight and length policy evaluation • Simple economic analysis • Simple mode shift policy evaluation • Mode accessibility analysis • Evaluating freight and non-freight trucking activities • Integrated future traffic forecast with passenger models
E- Economic activity models	• Land use model (i.e., uses that generate activity) • All components of 4-step models. • Trade volumes (in $ or tons) to truckloads conversion module	• Include applications listed under C and D • Land Use scenario analysis • Modal sensitivity/ economic analysis • Fuel sensitivity analysis • Advanced economic analysis • Truck traffic forecast consistent with Input/output matrices and economic growth scenarios
F- Tour-based model	• All component of 4-step • Modules to generate components of a tour such as (series of stops, depot location, shipment size)	• Include applications listed under A-E • Vehicle type (fuel and body type) utilization • Truck movement efficiency analysis (ratio of Empties ,less-than-truckload and full truck) • Truck route planning and optimization • Truck parking needs assessment • Pick up/delivery scheduling scenarios
G- Logistics/supply chain model	• Complex economic model including domestic and international trade factors	• Include all the above applications • Import/export policy analysis • National/international trade policy analysis • Tariff and border regulation strategy evaluation

Source: Fehr & Peers

Hybrid models, which take advantage of the benefits of the commodity flow and local truck models, including freight and other non-freight truck purposes, have proven to be the most effective modeling framework to date. Long-haul truck trips are modeled using the commodity flow database, which can be adjusted over time based on economic factors. Short-distance truck trips can be estimated as a function of local employment characteristics. The hybrid models are used in several metropolitan areas, and therefore have a theoretical framework that has proven applicable to metropolitan and regional models.

Despite their proven benefits and usefulness, hybrid models lack the ability to fully track logistics chains that have mixed long-haul and local components. The commodity flow data accurately estimate primary movements – that is, the flow from producers to consumers. The extensive information available on the amount of goods produced and consumed in the economy and the location of production and consumption sites helps ensure the accuracy of primary commodity flow data. However, not all of the secondary moves – the intermediate handling of goods at warehouses, distribution centers, and truck terminals – are effectively captured in commodity flow data. Sources such as the Bureau of Transportation Statistics/Bureau of Census Commodity Flow Survey, which surveys warehouses about commodity moves, do not distinguish primary and secondary flows. It is therefore impossible to associate these secondary flows with warehouse locations or warehouse activities. The hybrid models attempt to fill this gap by estimating all local truck trips through 3-step trip generation and distribution models. However, these models lack explicit links between the primary flows generated by the commodity flow data and the local truck trips. It is impossible to track flows of goods throughout the entire logistics chain to ensure consistency of the two approaches. The hybrid models do not allow for analysis of how changes in logistics patterns affect transportation demand.

Another disadvantage of the hybrid model is that it does not account for the trip-chaining characteristics associated with several different types of local truck moves. Both the commodity flow truck trips and the local truck trips are generated based on a trip being a single origin with a single destination. However, several types of trips (particularly those made within the metropolitan area) are by trucks that utilize a "sequentially unloading, return empty" truck trip pattern. Trucks leave their origins with a full load, make several stops to deliver partial loads, and return empty to their point of origin. Some trucks follow the reverse pattern, leaving their origin empty and returning with a full load after making pickups at multiple locations. These truck trip types are not well captured by the hybrid model. Service trucks also exhibit this trip chaining characteristic.

The state-of-the-art supply chain/logistics and tour-based models do take into account all of the drawbacks of the hybrid models. A supply chain and logistics-based model for freight can be considered analogous to activity touring models for passenger trips. However, while passenger tours almost always begin and end within the area served by MPO or DOT planning models, this is not the case for freight supply chains. These freight supply chains may begin, end, or have intermediate stops, including stops at truck-to-truck distribution centers, outside of the model region.

This is an important consideration in developing freight supply chain tours. While it is reasonable to synthesize passenger trip ends for populations within the region's model, limiting freight trip ends to synthesis of firms within the region is not sufficient. It is not reasonable for any region to have sufficient information for all of the firms located outside of its regions in order to synthesize freight trips for those firms. Further, the supply chains that travel between firms outside of the region without passing through the region may be of no interest to the region, even though understanding the supply chains that are formed that impact the region are constrained by the national universe of all supply chains.

The freight flows through a supply chain might not show the “last-mile” trip to the destination from the actual local supplier to the local consumer of freight. It has been shown that the major explanatory variable for the destination of freight are the wholesale firms, who can be expected to distribute that freight locally. Therefore, in addition to the freight flows allocated from the national O-D database, to gain a complete understanding of freight movements, it is necessary to develop a tour-based truck model that makes this last trip. It is probable that these tours will be made in trucks that consolidate many commodities; and that while the shipment of freight might be given between wholesaler and its customers, the actual path of the vehicle carrying that cargo will be in a tour from that wholesaler to many suppliers in a tour until the truck is empty and returns to the wholesaler and/or takes on another load. This model will have the ability to track all the trip chaining that state-of-the-practice models cannot do.

THE EXISTING SAN JOAQUIN VALLEY TRUCK MODEL

As part of the Model Improvement Plan (MIP) the Valleywide truck model that was originally developed in 2008 with a base year of 2000 and a primary forecast year of 2030 was updated to a base year of 2007 and future base year of 2040.

The original truck model was developed by Cambridge Systematics as a hybrid model based on 1996 Caltrans Intermodal Transportation Management System (ITMS) commodity data. Truck tons were then converted into truck trips using a ton per truck ratio, which also is referred to as the average payload. Average payloads were calculated for each commodity and vehicle class using the 1997 Vehicle Inventory and Use Survey (VIUS) data. County-level ITMS commodity flow truck trip data were then allocated to ZIP codes based on Standard Industrial Classification (SIC) employment data. The ZIP code-level trips were then allocated to the traffic analysis zones (TAZ) in the truck model based on total employment data for each TAZ. This truck trip table was then projected to the year 2000 based on the freight tonnage growth derived from the Federal Highway Administration (FHWA) Freight Analysis Framework (FAF 2) data for the State of California. Through trips (Valley pass-by trips) were added to the model based on survey data to match the cordon counts. Finally, short haul commercial trips such as service and utility vehicles, package and product delivery, construction transport, safety and public service vehicles, and business and personal service trips were added using trip generation rates form QRFM and other FHWA available research at the time.

The model was designed to generate truck volumes measured in terms of average daily traffic. Diurnal factors for trucks were derived from truck counts for each county. The truck model output reports truck volumes based on truck classes that the CARB (California Air Resources Board) defines as medium heavy-duty and heavy-heavy duty for regulatory purposes (more than 14,000 pounds gross vehicle weight rating). Medium-heavy duty trucks (MHDT) have a gross vehicle weight rating (GVWR) between 14,001 and 33,000 pounds. Heavy-heavy duty trucks (HHDT) have a GVWR of 33,001 pounds or more. A multiclass equilibrium assignment was performed and validated by comparing model truck volume outputs to truck counts in the Caltrans report *Annual Average Daily Truck Traffic on the California State Highway System*. Figure 7 shows an overview of this model and how it was connected with the passenger models.

The 2007 model maintained the overall structure of the original truck model and focused on updating the input data and model components and improving truck model validation. The countywide commodity flow table was adjusted to match FAF 3 data for year 2007. The short haul module was refined to better represent the medium and heavy vehicle ratio in each county. More validation tests were conducted to ensure the reasonable performance of the model. This validation process was performed at county level across three dimensions: truck type, facility type, and time period by comparing vehicle classification counts with model estimates and comparing the trip length distribution of trucks by type with target VMT values for medium and heavy trucks. The 2007 model can:

- Inherently calculate emissions from heavy trucks
- Estimate traffic in major activity centers in order to analyze congestion impacts on major truck routes
- Analyze land use conflicts between truck intensive land uses and residential or commercial developments
- Predict truck flows by truck class to analyze access to activity centers for heavy trucks

The Valleywide truck model generated daily truck tables for all 8 counties in the Valley. Since the numbering of zones and level of aggregation in the Valleywide truck model and each of the counties' passenger models are different, there is a separate process to extract the subarea truck tables and renumber the zones to create truck tables for each of the counties. Since this process is not seamlessly integrated in the MPOs' passenger models and there are two independent input databases for passenger and truck models, it is difficult for modelers at MPOs to develop and evaluate scenarios.

Although the validation statistics of the 2007 model were improved significantly relative to the original model, they are still not sufficient to use the model for local applications. According to our survey from modelers at San Joaquin Valley MPOs, the truck model has not been used in any analysis or scenario applications after it was updated in 2011 for the Valley's Inter-Regional Goods Movement Study.

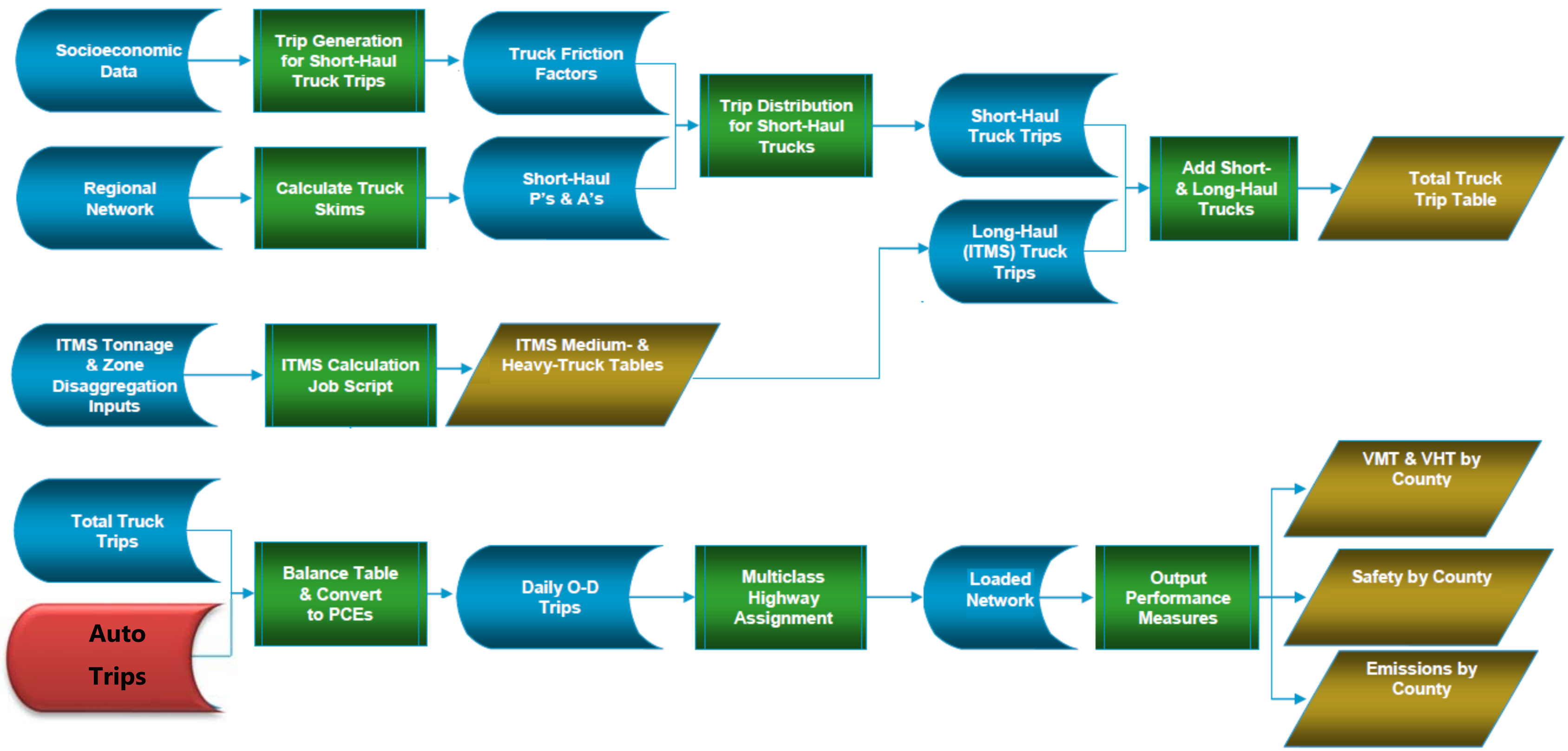


Figure 7. Overview of San Joaquin Valley Truck Model

CALIFORNIA STATEWIDE FREIGHT FORECASTING MODEL

The California Statewide Freight Forecasting Model (CSFFM) is a policy-sensitive commodity-based freight model developed for the State of California to forecast future freight flows on the transportation network under various policy and investment scenarios. It was developed primarily within the Citilabs CUBE platform. The first generation of the model was developed at institute of Transportation Studies at UC Irvine. The **CSFFM 1.0** was calibrated and validated using available truck count data at Weigh-In-Motion sites in California for the years 2007 and 2010, forecast year 2020 and 2040.

The model will address socioeconomic conditions, freight-related land use policies, environmental policies and multimodal infrastructure investments. The model comprises five core modules: The Commodity Module, Mode-Split Module, Transshipment Module, Seasonality and Payload Factor Module, and Network Module (Figure 8).

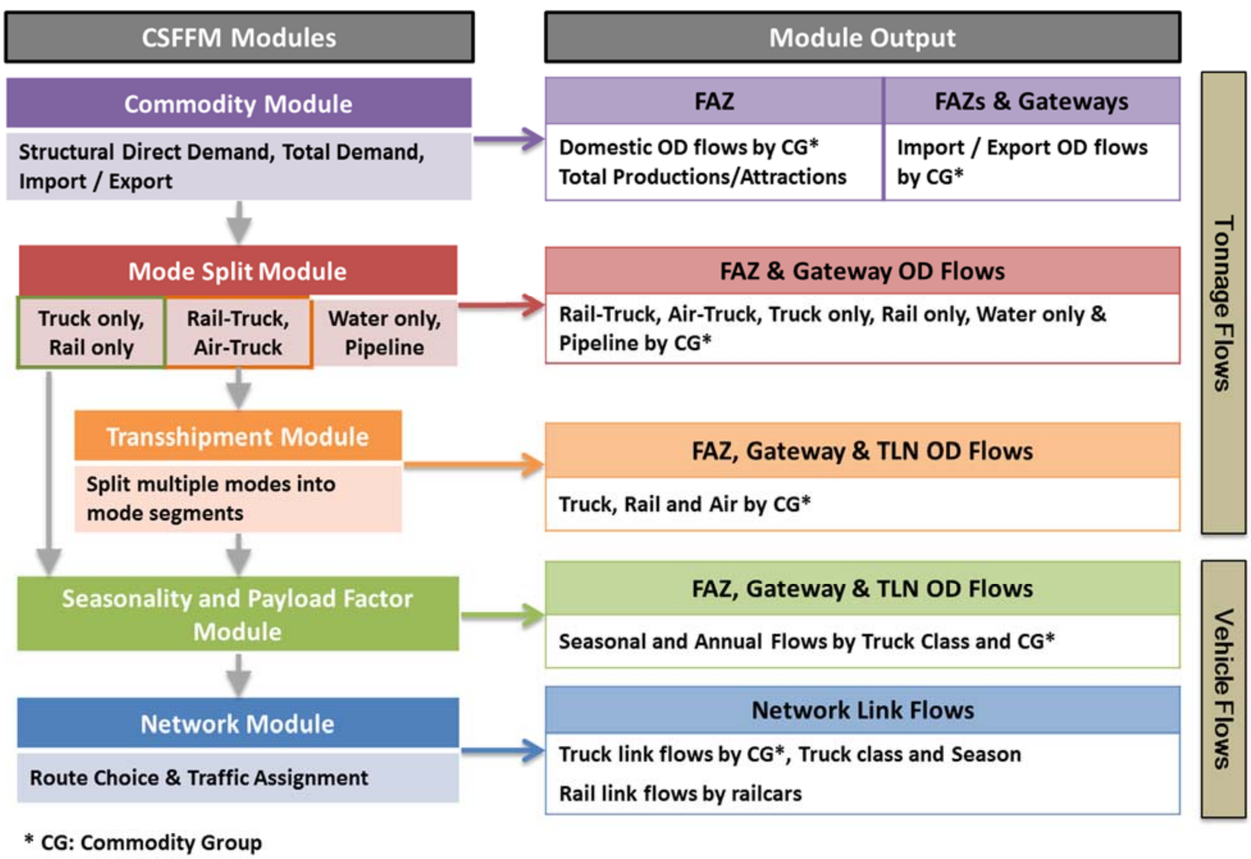


Figure 8. CSFFM Primary Modules

The Commodity Module consists of the total generation, domestic flow distribution, and import/export gateway distribution steps. From these three steps, the module produces production and attraction and distribution of commodities by tonnage based on demographic and economic data as well as impedance information (i.e., travel time and cost). The Mode-Split Module determines the mode share for each mode corresponding to each origin-destination pair. Incremental logit models are used in this module to evaluate the impact of changes in mode attributes. The Transshipment Module breaks intermodal trips into their component segments by mode and assigns commodity flows at the transport logistics nodes (TLNs). The Seasonality and Payload Factor Module uses truck tonnage, multimodal information, and trucks from transshipment to produce seasonal and annual flows by truck class and commodity group. Lastly, the Network Module consists of route choice and traffic assignment. This module uses multi-class assignment to assign trucks to the network and all-or-nothing for the rail assignment. The outputs are truck flows in four truck categories at the network level; rail tonnage flows at the network level; and air, water and pipeline tonnage flows at the Origin-Destination (OD) matrix level.

The analysis zone scheme comprises 97 Freight Analysis Zones (FAZs) within California that are defined at the county and sub-county level, and conform to MPO and air basin boundaries. There are 38 import/export gateways (19 land ports, 8 airports, and 11 seaports), and 31 TLNs (13 airports and 18 rail terminals including five virtual rail terminals) inside of California. Outside of California, the scheme includes 118 domestic regions and 8 international regions that conform to the Freight Analysis Framework (FAF) zones.

The model includes fifteen commodity groups (CGs) based on the aggregation of the two-digit Standard Classification of Transported Goods (SCTG) commodity classes used by FAF.

Several key features of the CSFFM facilitate compatibility with other regional and statewide models in California. The FAZs are defined at the county and sub-county level. In addition, all FAZs conform to existing MPO and CARB air basin boundaries, and are composed of CSTDM TAZ aggregations.

The **CSFFM 2.0** maintained the original structure with focus on updating the input data for base year 2015 using FAF 4 data for year 2012, improving model validation using static and dynamic tests and develop user friendly interface to facilitate evaluating different planning level scenarios.

CSFFM 2.0 has a scenario development tool to help the users modify the input data easily and summarize the output data in various forms. Figure 9 shows the steps required to develop a scenario in the freight model.

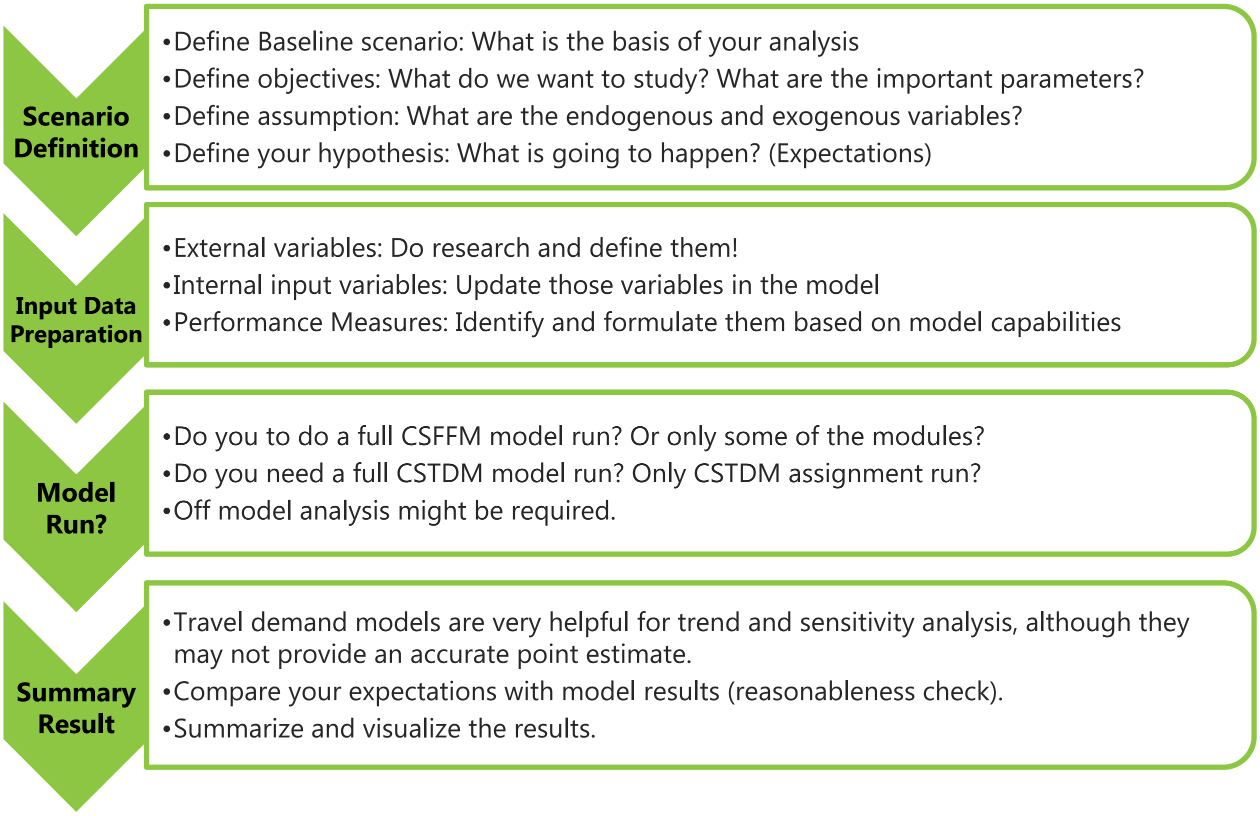


Figure 9. Scenario Development Process

The scenario development tool allows for more efficient sketch model scenario creation. This Excel-based tool can edit a wide range of model input files using a user-friendly graphical interface. Without this tool, the user has to find the input files from the CUBE catalog, then find the desired zone(s) and variables and modify the csv files directly. Figure 10 shows the main menu. This is where the user will identify the folder and file path to model input and output files.

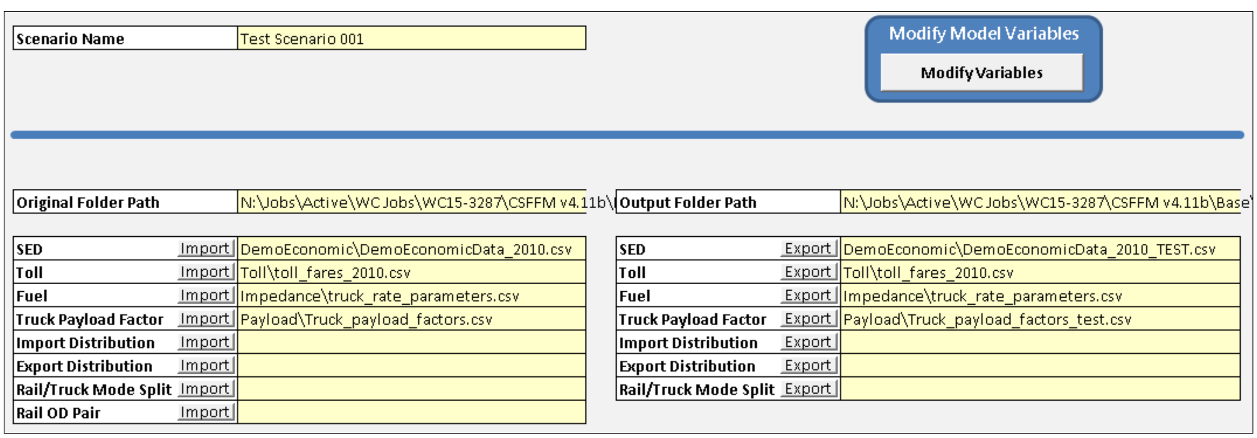


Figure 10. Scenario Development Tool: Initial Menu

Figure 11 shows the Model Variables List menu. The user can edit model variables, reset model variables, generate scenario difference reports, and export the new model scenario input files. The model variables Rail Waybill and Rail Truck Mode Split are placeholders for future enhancement of the model.

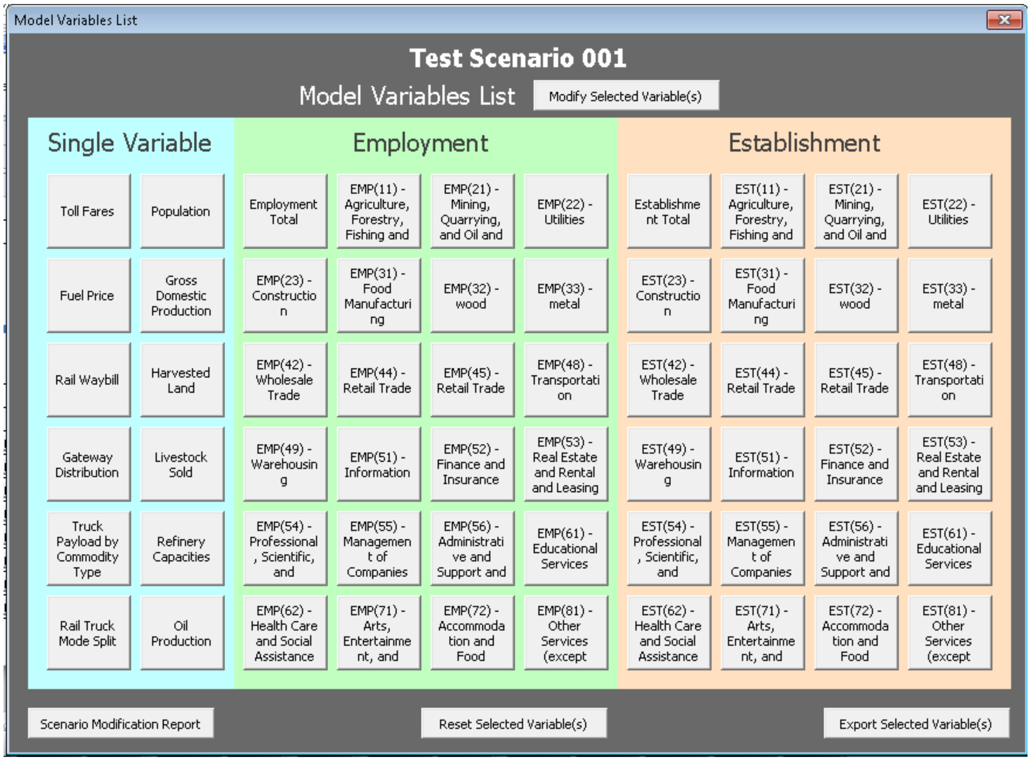


Figure 11. Scenario Development Tool: Variable Selection Menu

This is a flexible tool for MPOs to easily change the land use and parameters of the model in their region.

CSFFM 3.0 is currently under construction, expected to deliver by year 2018. The model will have major improvements in following areas:

- Update input data for base year (2018) and future years (2040 and 2050) to be consistent with the latest RTP for each MPO
- Refine the parameters for each of the special generators (Import/ Export process)
- Revise payload and seasonality module with the CA-VIUS data
- Estimation of empty truck flows
- Improve Transshipment module functionality to be more transparent, and sensitive to multi-modal policies
- Add a non-freight and short haul truck module to account for all commercial trucks in VMT and emission analysis.
- Improve validation of the regional trips at over 25 screen lines
- Improve disaggregate process
- Develop a process for seamless integration with statewide passenger model

RECOMMENDATIONS

Understanding the opportunities and challenges associated with freight demand modeling is an issue of great importance in transportation planning. The selection of a suitable model for forecasting freight traffic demand is also of major interest. This white paper provides a systematic review of the state-of-the-practice in freight demand forecasting models in order to guide the selection and adoption of such models into the San Joaquin Valley MPO's transportation planning process.

The review of freight modeling techniques reveals that there is no single model able to meet all of the needs identified by the user group participants. By incorporating features from several of the existing modeling frameworks, it would be possible to design a freight modeling framework suitable for addressing public and private sectors' needs. Although the tour-based models hold the greatest promise among the models explored in this study for future refinement and implementation, the model developments requires more detailed input data as well as more budget. Research efforts are currently being devoted to the development of such models and the databases needed to develop and support them. However, in our opinion true goods movement modelling is not yet sufficiently developed to the point where it is easily adoptable by most urban travel forecasters at affordable cost.

Our goal is to provide a framework that makes the best use of available data sources and statewide and regional tool. The most complex and advanced tool is not always the best tool for a specific application. Sometime a simple sketch planning spread sheet tool can provide good information and insight for decision making with low cost and high flexibility. Therefore we requested the user group participants to identify their needs and priorities. Consistency with statewide model provides an opportunity to easily integrate the input data (land use, commodity flow, trip generation and distribution rates, network characteristics) into the Valley model and use the output data (truck od tables, commodity od tables, regional VMT, …) where needed.

RECOMMENDED FREIGHT MODELING FRAMEWORK

After reviewing the available modeling methodologies and their associated cost, the various needs of San Joaquin Valley MPOs for freight planning, the following options are available:

1. Updating the Valley Truck Model with latest socio demographic data, improve the structure to seamlessly integrate with each county passenger model and enhance the model to provide desired performance measures. Develop a plan to maintain and update the model periodically and provide training for MPOs to be able to use the model as needed.

2. Adapt the statewide freight model and develop a process to disaggregate a sub area model for each MPO and integrate with their passenger model.

Option 1 requires major investment to update the Valley truck model and continuous commitment to maintain the model and training the staff for new applications. However, the model would be customized to the local needs and the MPOs have more control about the structure of the model and related assumptions.

Option 2 requires Valley MPOs' close coordination with Caltrans modeling staff to ensure that their projects are properly included in CSFFM. The input data for future forecast year are consistent with Valley's assumptions and modeling staff at each MPO are familiar with the model application and developing different scenarios. The advantage of this option is that Caltrans would maintain the model, provide regularly updates and offer training for all MPOs.

Considering the above notes, a hybrid framework is recommended, where option 2 is adapted and procedures will be developed to address all local needs. Under this framework there will be no need to maintain a valleywide freight model; every MPO will have a freight module integrated to their Passenger model. This recommended framework is summarized in two steps and explained in Table 4 and Table 5 :

- Valley Freight Data Plan
- Valley Freight Model Update Plan

Table 4. Valleywide Freight Data Plan

Step One
1. **Maintain an inventory of truck routes, truck parking, major freight activity centers.** 2. **Maintain a database of classification counts for major arterials and regional screen lines** 3. **Prepare a maintenance plan and review/update the data base every 5 year.** 4. **Maintain a single set of input data base for passenger and freight models.**
• **As part of *I-5/SR-99 Freight Corridor Study* and *Sustainable Implementation Plan Study* a lot of freight related data have been collected and geocoded. This geo database can be published on the Valley website as a valuable resource for practitioners.** • **The shared input data between passenger models under MIP and freight model (such as land use information or network information) must be consistent and seamlessly integrated.**

Table 5. Freight Model Update Plan for each MPO

Step Two
1. Maintain the consistency with California Statewide Freight Forecasting Model (CSFFM). Ensure the consistency of model's assumption
Maintaining consistency of the Valley MPO models with CSFFM can provide the opportunity to easily integrate the information provided by CSFFM into the Valley model. The following elements are few examples: • **Commodity groups definition** • **Regional flow (import/ export flows)** • **Route choice patterns, through trips and local trips** • **Share of each mode** • **Vehicle classification.** **Coordinate closely with Caltrans modeling group and providing future land use forecast will ensure that the statewide model can forecast volumes consistent with MIP**
2. **Develop a sketch freight planning tool for quick inter-regional commodity flow analysis**
• **It can be an efficient spread sheet tool based on disaggregated FAF data from CSFFM base year. Compiling the data in a data visualization packages (such as Tableau) can help to quickly make filters and plot the distributions and derive basic statistics about commodity flow between origin and destination sets.** • **The tool can include the distribution of long-haul trucks (by origin and destination) on major corridors derived from select link assignment run of CSFFM model or GPS trajectories. This information will help to coarsely estimate the percentage of trucks that might shift their route when a comparable alternative route is provided.**
3. **Modify Valleywide truck model to include new modules and user friendly interface for easy and seamless integration with the MIP passenger model and statewide model**

•	**Ensure that the Valleywide truck network has all of the required attributes for multi class assignment (truck speed, functional class, grade, capacity)**
•	**The inter-regional truck trips (I-X , X-I , X-X) trips can be derived easily from CSFFM and disaggregated to the Valley vide TAZs. This is important for** the **Valley truck model since it is located on the** "spine" **of the State.**
4.	**Include truck trips by their purpose: freight and non-freight trips**
•	**Heavy duty trucks are not as sensitive to network changes as passenger vehicles. The number of alternative truck routes between a**n **O/D pair is usually very limited. Information about truck purposes helps to evaluate the impact of capital projects, corridor improvements and last mile connectors accessibility based on targeted trucks by trip purpose.**
5.	**Improve model validation on local level and conduct model sensitivity test**
	In order to use the model to evaluate the impacts of smaller projects at local level, it is important to improve the validation of the model and focus on more local screen lines as well as regional screen lines.

REFERENCES

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- Cambridge Systematics, Inc., Quick Response Freight Manual (QRFM II)– Part II, prepared for Federal Highway Administration, July 2007.
- Cambridge Systematics, Inc., Freight-Demand Modeling to Support Public-Sector Decision Making, prepared for Transportation Research Board, NCFRP Report 8, 2010.
- Boerkamps and van Binsbergen, GoodTrip – A New Approach for Modelling and Evaluation of Urban Goods Distribution, Delft University of Technology, and The Netherlands Research School for Transport, Infrastructure and Logistics
- Fischer, M. J., et al., Cambridge Systematics, *An Innovative Framework for Modeling Freight Transportation in Los Angeles County*, presented at the 84th TRB Annual Meeting, January 2005.
- J.Y.J. Chow, C.H. Yang, A.C. Regan, State-of-the-art of freight forecast modeling: lessons learned and the road ahead. The Journal of Transportation, 37 (6), 2010, 1011-1030.

Other Recent Modeling resources and guidelines

- NCHRP Report #735: Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models
- NCHRP Report #716: Travel Demand Forecasting: Parameters and Techniques
- NCHRP Project 836-B Task 91 Final Report: Validation and Sensitivity Considerations for Statewide Models
- NCHRP Project 08-36 Task 70: National Travel Demand Forecasting Model
- NCHRP Synthesis 358: Statewide Travel Forecasting Models
- NCHRP Report 606: Forecasting Statewide Freight Toolkit
- NCHRP Project 08-36, Task 76c White Paper: Statewide Travel Demand Forecasting. Prepared for: "Meeting Federal Surface Transportation Requirements in Statewide and Metropolitan Transportation Planning: A Conference", 2008. (Modest update to NCHRP Synthesis 358)
- NCFRP Report 19: Freight Trip Generation and Land Use, 2012
- NCFRP Report 37: Using Commodity Flow Survey Microdata and Other Establishment Data to Estimate the Generation of Freight, Freight Trips, and Service Trips, 2016

APPENDIX I-SAMPLE SCENARIO ANALYSIS USING CSFFM

As part of training material and discussion topics developed for the freight user group workshops, it was suggested to prepare a sample of scenario analysis using Statewide Freight Forecasting Model. The objective is to define the step-by step process in developing hypothesis, preparing the input data, estimation of new model parameters and setting the model run. Three scenarios are selected for this training purpose:

1. A corridor improvement scenario that impact the truck routing
2. A land use scenario that change the commodity flow distribution
3. A network improvement scenario that significantly change the mode shares

In this section, the above 3 scenarios will be reviewed.

CORRIDOR IMPROVEMENT-SR198

SR 198 is an east-west corridor connecting SR 99 and I-5, passing through Visalia in Tulare County, Hanford and Lemoore in Kings County and Huron in Fresno County (Figure 12). This Corridor has mostly one lane in each direction, except the middle part between 25th Avenue in Kings County and SR 99 in Tulare County, where it has two lanes in each direction. The current traffic volume on SR 198 corridor is shown on Figure 12. The truck traffic on this corridor is significantly higher closer to SR99.

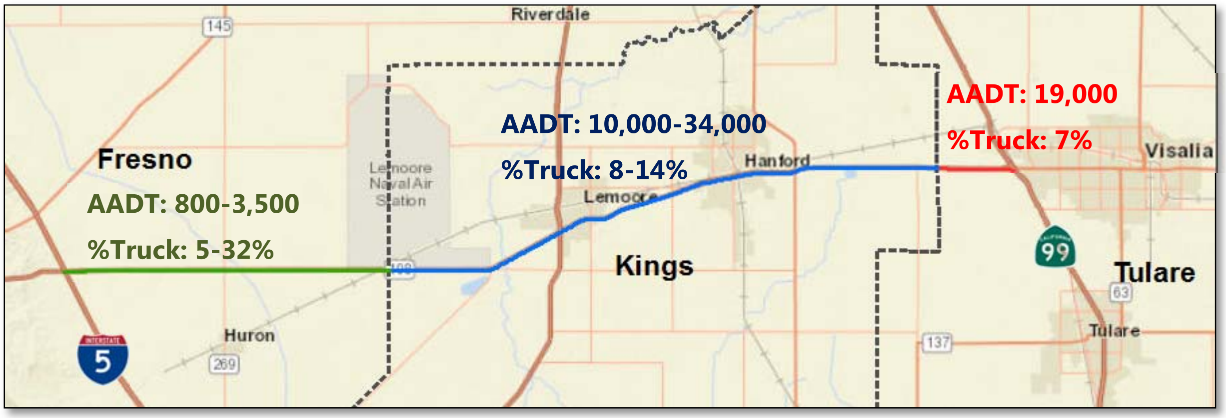

Figure 12. SR 198 Corridor Traffic

This route is parallel to SR 46 and SR 58 in Kern County (Figure 13). It is the longest east-west corridor between SR99 and I-5, about 47.5 miles. The long length of this corridor (relative to SR 58 and SR 46) makes it a less favorable route for the truck trips coming from other states via I-15 and I-40.

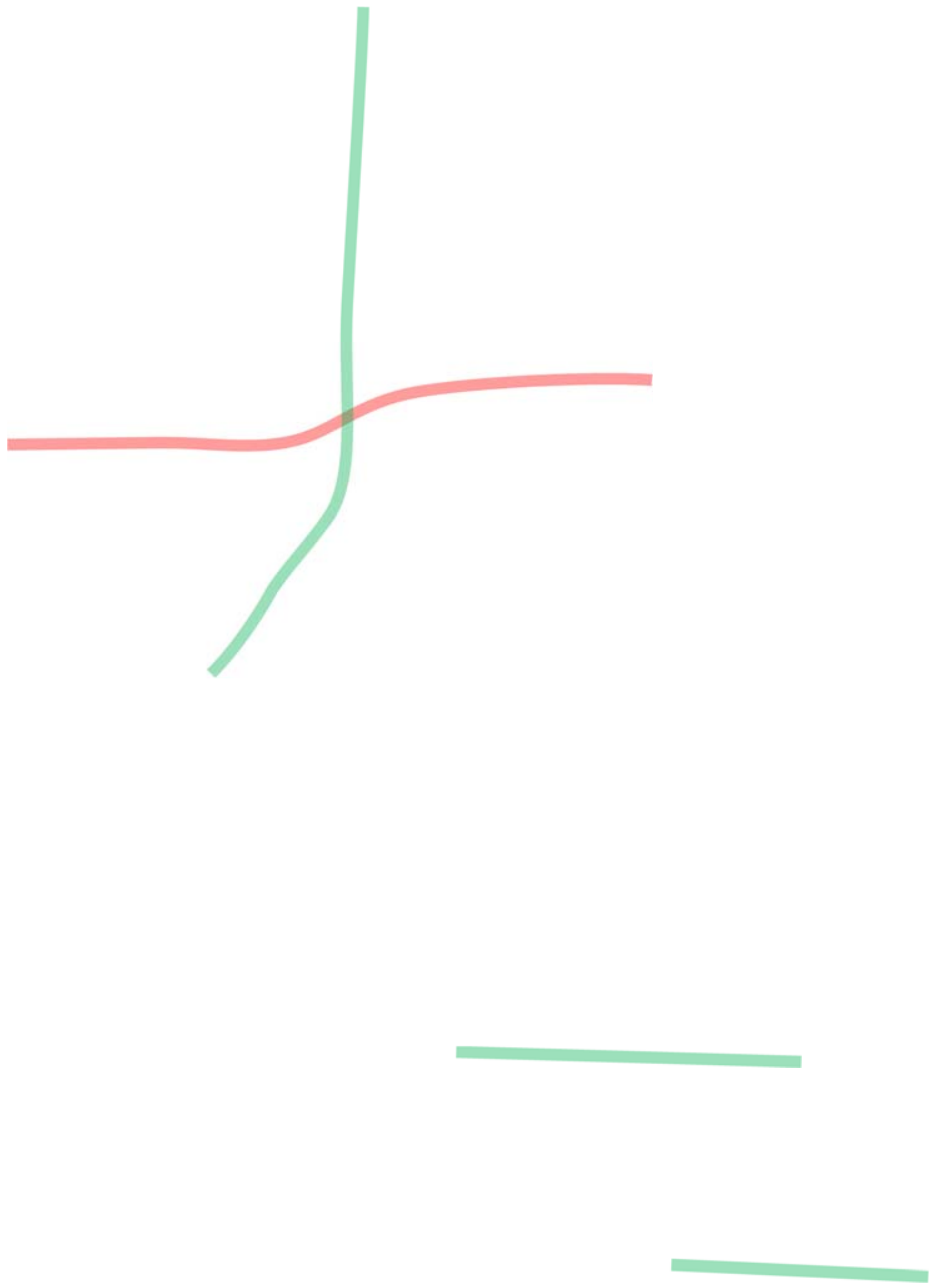

Figure 13. SR 198 Corridor and alternative I-5/SR99 connectors

The average truck speed during the peak period on this corridor is less than 50 mph. However, this corridor passes through rural areas with several access roads on each side that provides vehicle access to adjacent farms. These drive ways may increase the total travel time across the corridor. Figure 14 shows the major industries near this corridor.

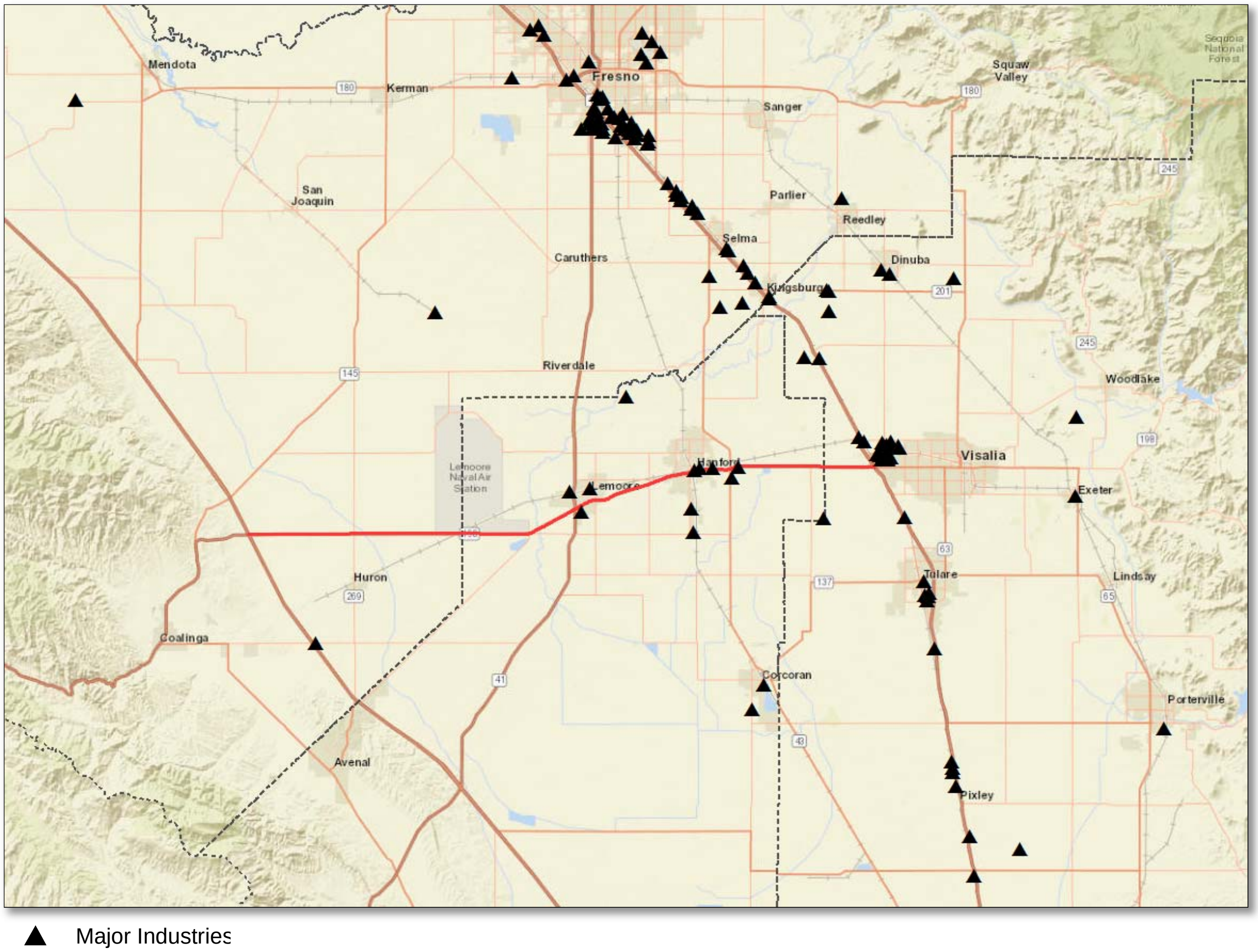

Figure 14. Major Industries Near SR 198 Corridor

SR 198 is the main route connecting industries at Visalia, Tulare, Hanford and Lemoore to the Interstate network. Figure 15 shows the existing origin and destination of heavy-duty truck trips travelling through this route. As shown in the figure the majority of traffic on SR 198 is within Tulare and Kings Counties.

Figure 15 is generated using the “select link” function in Cube. This function traces all the trips travelling through a specific link (in this example SR 198). This is a helpful analysis to identify who are the users of each facility, where they come from and where they are going.

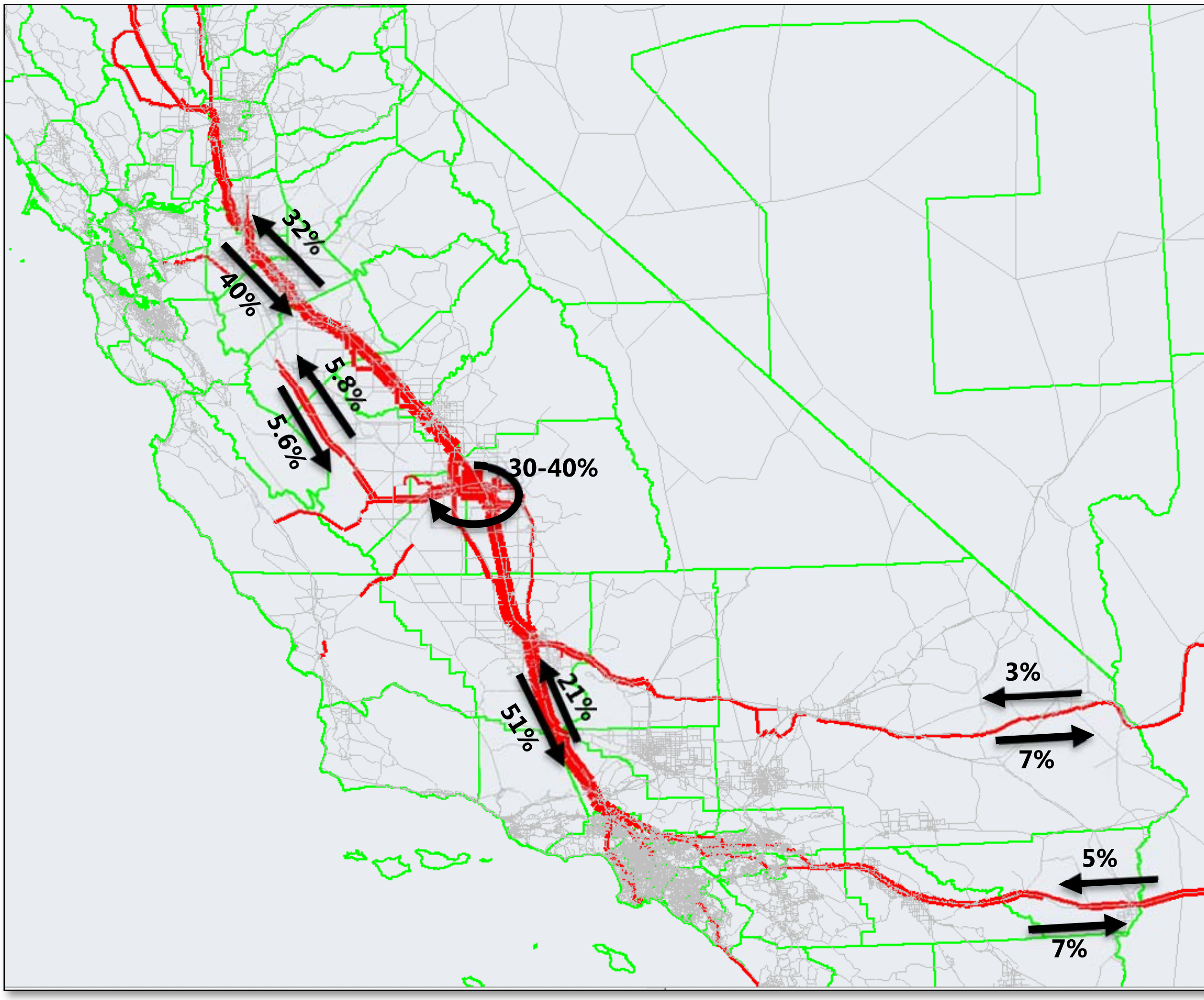

Figure 15. Existing Trip Distribution for SR 198 Corridor

Scenario Assumptions

The following improvements are assumed for SR 198 between SR 99 and I-5 for this analysis:

- The corridor has 3 lanes in each direction
- Trucks can reliably travel 55 mph along the corridor. All the delays due to signalized intersections are removed.

Figure 16 shows the distribution of truck trips traveling on SR 198 after the above improvements are implemented

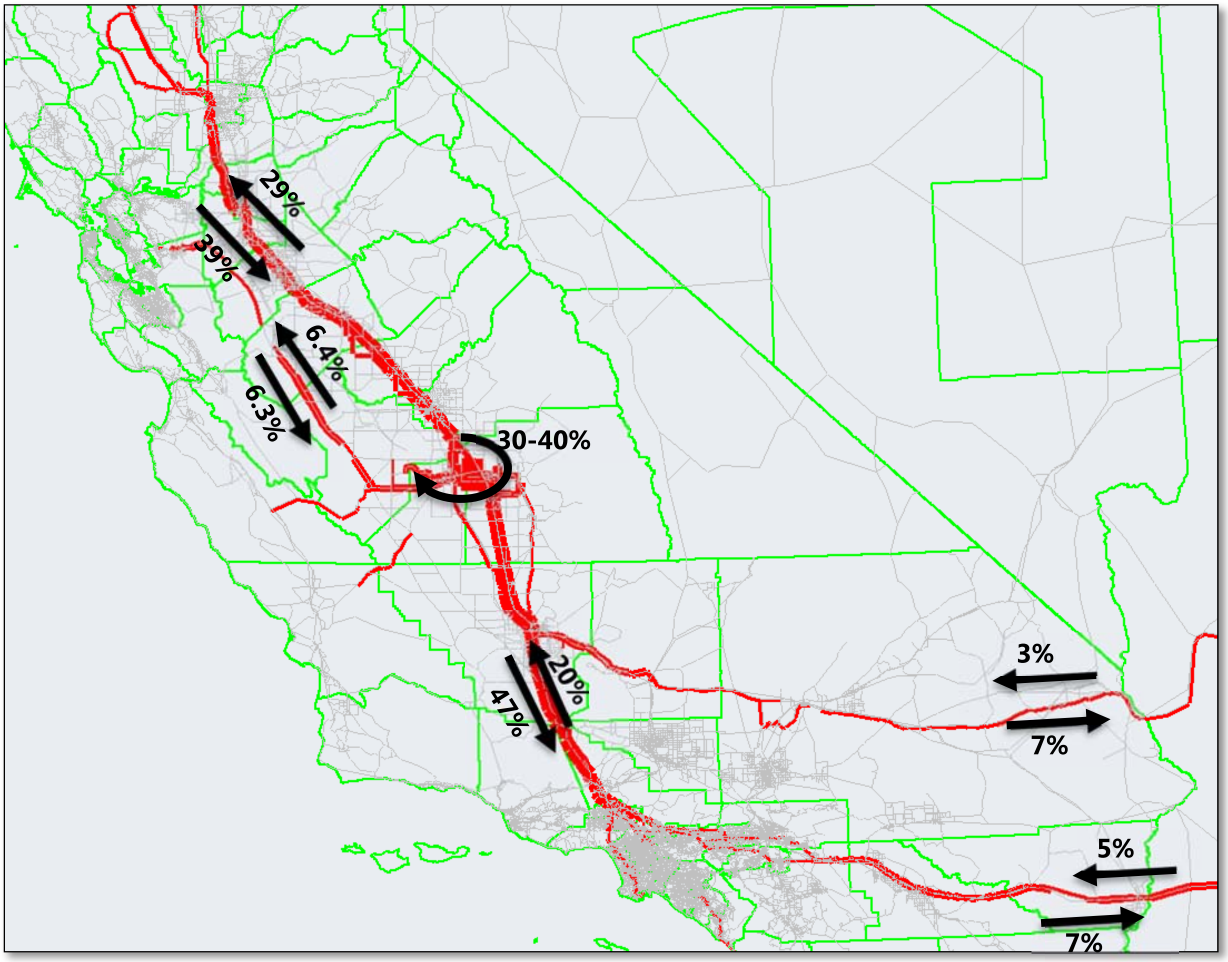

Figure 16. Corridor Improvement Scenario - Trip distribution for SR 198 Corridor

To better understand the overall change in truck traffic patterns, we can use difference plots. In Figure 17, blue lines represent increase in truck volume in corridor improvement scenario relative to baseline scenario, and red lines represent decreases in truck volume. As shown in Figure 17, truck traffic on I-5 between SR198 and I-580 has increased, while the traffic on parallel section on SR99 has decreased.

We can also see that there is slight decrease in truck volumes on other I-5/SR99 connectors. The change in traffic pattern is more significant in major arterials near SR 198. Since 40% of the truck traffic on SR 198 corridor is within Tulare and Kings Counties, improving this corridor will shift local truck traffic from major arterials to this corridor.

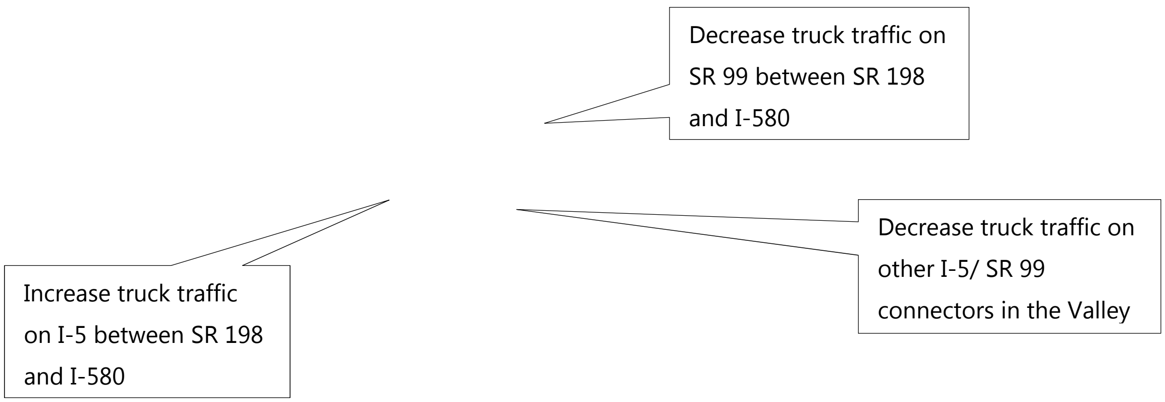

Figure 17. Impact of SR 198 Corridor Improvements on I-5 and SR 99

Conclusion

SR 198 is the main access route for industries in Visalia and Kings County. It can also provide an alternative route between Central Coast and metropolitan areas outside California. However, due to its geographic location, it is not a desired route for through traffic (trips started and ended outside the valley). Less than 10% of the truck traffic on this route is through traffic. The major benefit of improving this corridor is shifting truck traffic from local arterials to SR 198. This will improve the overall safety of the neighboring communities.

Reducing travel time on SR 198 would have slight benefit of reducing congestion on SR 99 between SR 198 and SR 120 by shifting some of the truck traffic to I-5.

In Figure 17, we can also see that truck volume has changed in some parts of the network in a way that is not reasonably related to the analysis scenario. TCSFFM uses the Cube Stochastic Traffic Assignment method, which may have created some minor statistical "noise." It is important to review the output of any scenario developed by travel demand models to ensure the reasonableness of the results.

LAND USE SCENARIO- SEVERE DROUGHT

Drought is defined as "… a period of drier-than-normal conditions that results in water-related problems."[5] Droughts are related to inadequate amounts of precipitation, soil moisture, or streamflow or groundwater levels.[6] The most recent drought in the State of California began in October 2011 with no end in sight.[7] Rainfall has been between 54 to 75% lower than the normal rainfall amounts during the past five years.[8] Droughts have a number of impacts on water supply and demand, but especially impact the agriculture sector. California farmers rely heavily on water for crop irrigation and dairy and cattle production. Thus, as water supply continues to wane, the agricultural sector may experience continued pressure to constrict, diversify, or shift to less water-intensive activities. While the agricultural sector contains aspects of nimbleness, production variables and sector trends may take many additional years to clearly understand.

To evaluate the performance and sensitivity of CSFFM under such situation we developed the "Extensive Drought" Scenario. This freight analysis scenario accounts for drought impacts on truck trip generation, distribution, and truck vehicle miles traveled throughout the Freight Analysis Zones. We are focusing on explaining each step of the process of developing a scenario, collecting relevant information to understand trends and patterns and translating real-world variables into model variables. To respect the scope and schedule of this study, final assumptions are made anecdotally. Figure 18 and Figure 19 summarize the process and assumptions for this this scenario.

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[5] United States Geological Service. http://ca.water.usgs.gov/data/drought/
[6] Ibid.
[7] National Oceanic and Atmospheric Administration. https://www.climate.gov/news-features/event-tracker/how-deep-precipitation-hole-california
[8] Ibid.

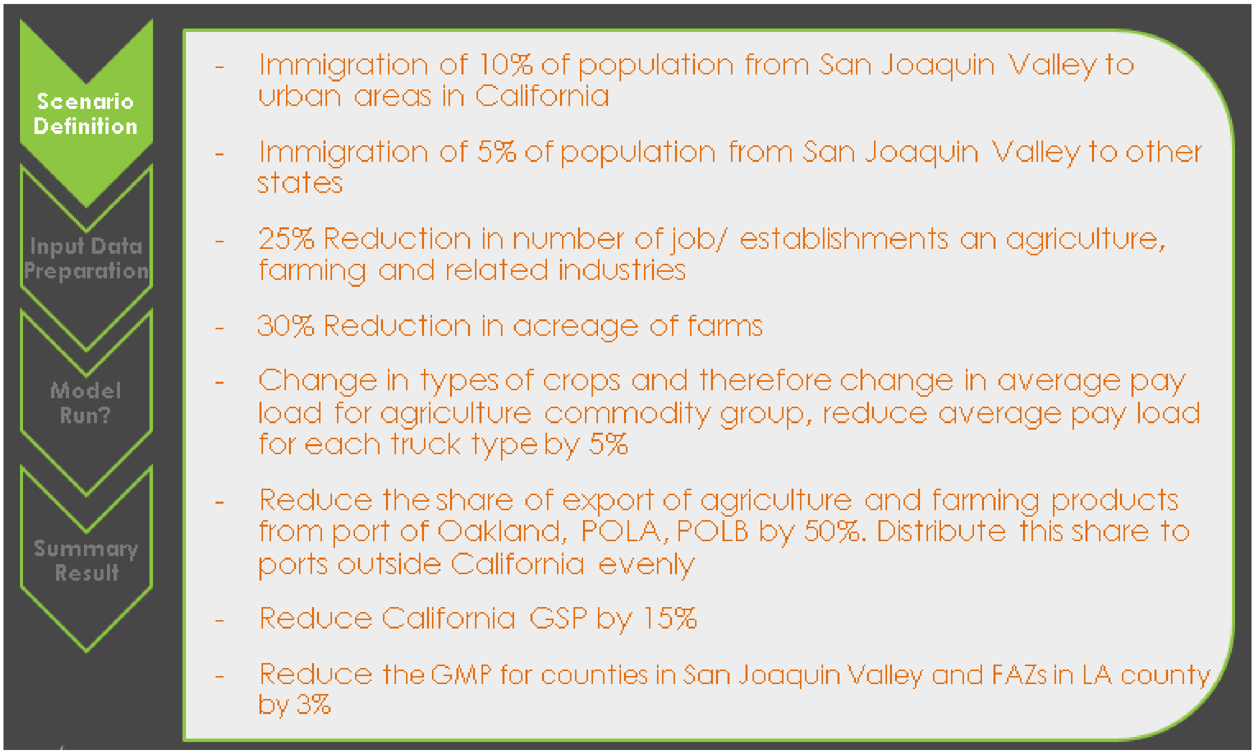

Figure 18. Scenario Two: Extensive Drought Assumptions

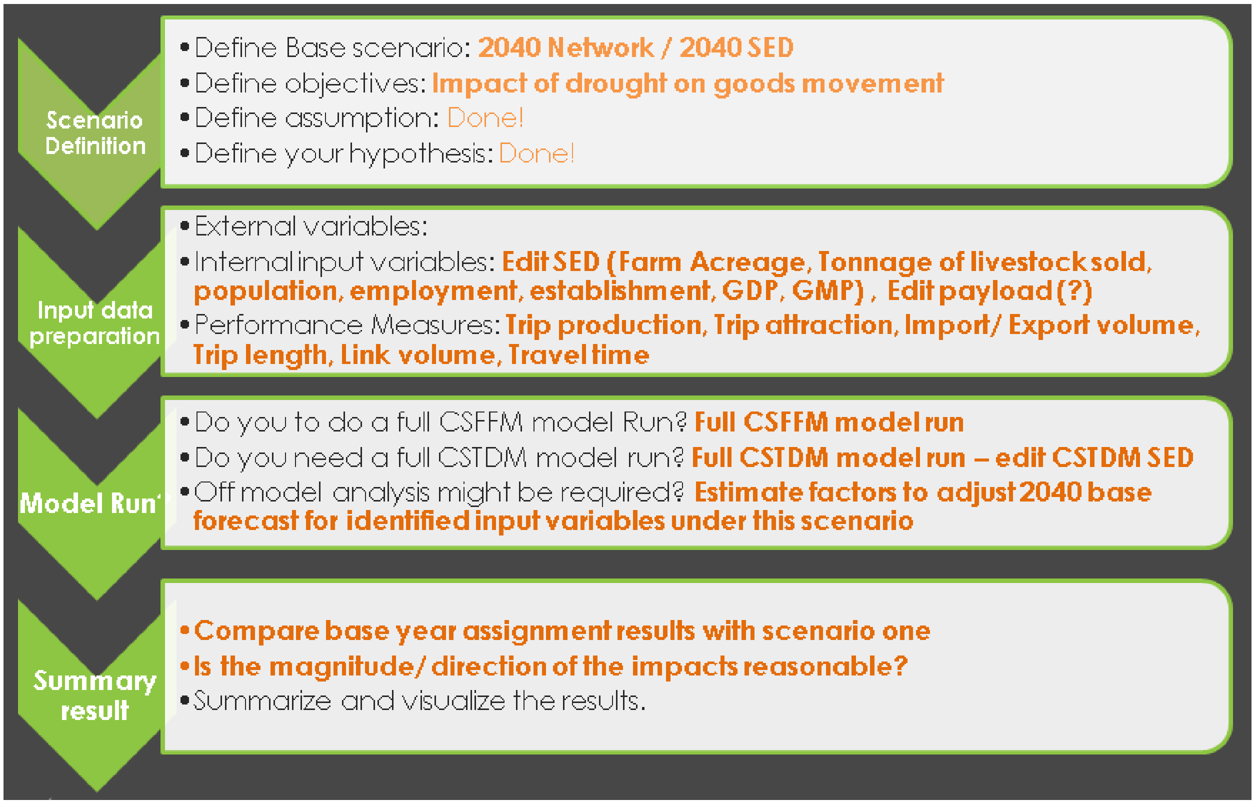

Figure 19. Scenario Two: Extensive Drought Data Preparation

Since this scenario has a major land use update, a similar scenario has to be developed for passenger model to estimate the new travel time with additional congestion. Given the complexity of the population synthesizer in CSTDM, only employment data has been updated in CSTDM scenario for this analysis.

IMPACT OF DROUGHTS ON GOODS MOVEMENT AND FUTURE TRENDS

The CSFFM variables include a number of agriculture-related measures, which may be impacted by the drought. The harvested land variable assesses the number of acres from which farmers harvested a crop. California harvested land acres increased 5% between 2007 and 2012 from 7,633,173 to 8,007,461.[9]

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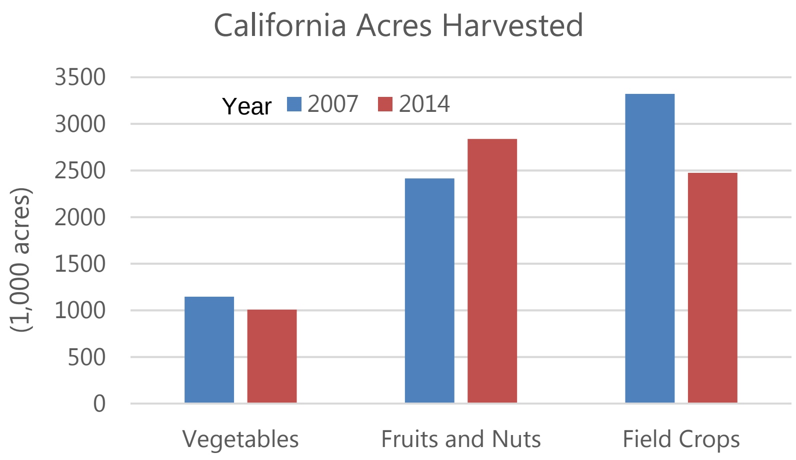
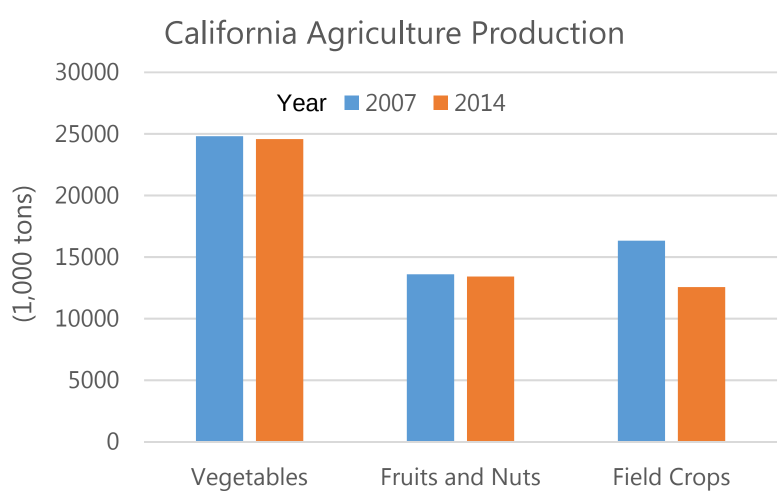
[9] United States Department of Agriculture. *Census of Agriculture.* http://quickstats.nass.usda.gov/?source_desc=CENSUS



Source: https://www.cdfa.ca.gov/statistics/

Figure 20. California Acres Harvested in 2007 and 2014

Agricultural production shifted in a number of the agricultural production sectors during the past decade, as shown in Figure 20. Examples of this shift include an increase in the production of almonds, walnuts, pistachios and other tree nuts and fruits. Simultaneously, grain acres and production decreased, especially rice and cotton production, while vegetable acres and production both decreased slightly[10] as shown in Figure 21.



Source: https://www.cdfa.ca.gov/statistics/

[10] United States Department of Agriculture. "California Drought: Crop Sectors." http://www.ers.usda.gov/topics/in-the-news/california-drought-farm-and-food-impacts/california-drought-crop-sectors.aspx#Rice

Figure 21. California Agriculture Production

The full shift to tree nuts has not yet been realized, as it takes anywhere from five to 15 years for these trees to mature to full production. For example, almond production between 2011 and 2014 decreased by 8% (Figure 22); however, during the same time period, the bearing and total almond acreage increased.[11] The drought has impacted the size, weight, and nut density of the tree nut crops as well.[12]

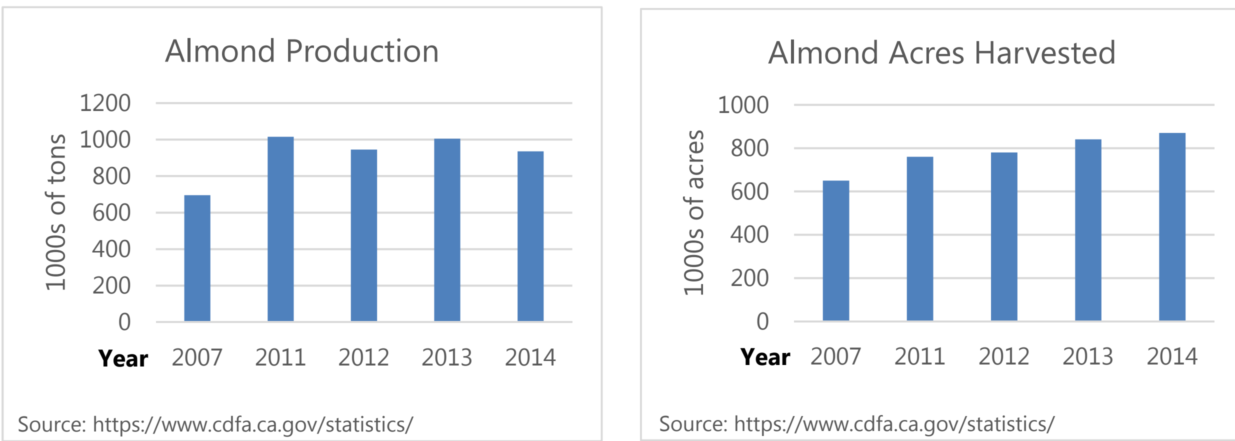


Figure 22. Almond Production and Harvest

The drought has also caused an increase in the amount of fallow land in California. Fallow land is defined as land that is suitable for agricultural production, but , is not used for production purposes by farmers due to impacts such as the water shortage. The USDA CropScape data tool creates estimates of land usage based on satellite imagery. These estimates point to an overall increase of 33% in fallow land from 2014 to 2015,[13] as shown in Figure 23.

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[11] Ibid.
[12] Ibid.
[13] United States Department of Agriculture National Agricultural Statistics Service. "CropScape." https://nassgeodata.gmu.edu/CropScape/. It should be noted that these are estimated values.

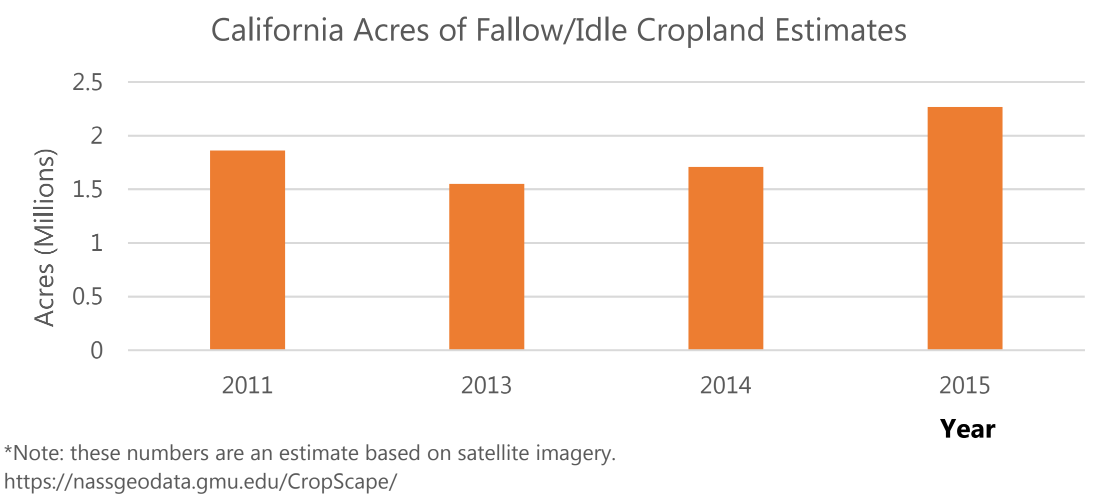


Figure 23. California Acres of Fallow/Idle Cropland Estimates

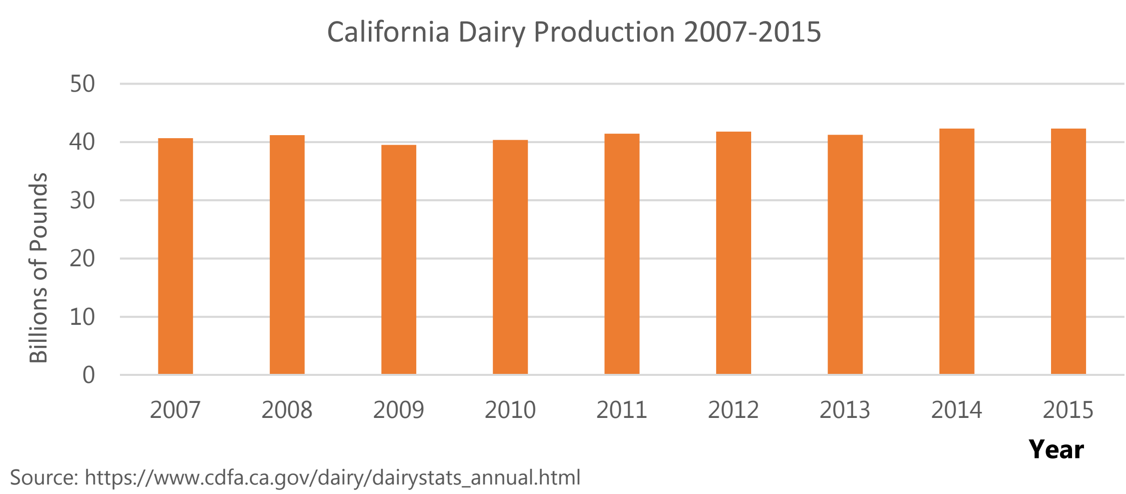


Figure 24. California Dairy Production in 2007 and 2015

Interestingly, the drought had minimal effect on dairy production in California, as shown in Figure 24. Bulk milk production has hovered around 40 to 42 billion pounds the past five years, with 2014 as the high point.

If the drought continues, farmers may be forced to shift production practices from crops that consume large quantities of water to those that consume less. For example, cotton yields a lower income per acre while consuming large quantities of water. Tree nuts, however, yield high incomes per acre while also consuming large amounts of water for production and processing purposes, as shown in Figure 25. Thus, until water costs or scarcity outweigh the income potential for tree nut crops, production of these commodities will continue to increase. However, the economic consideration of cost of production, including the purchase of water, will continue to shape production patterns and practices of all agricultural commodities.

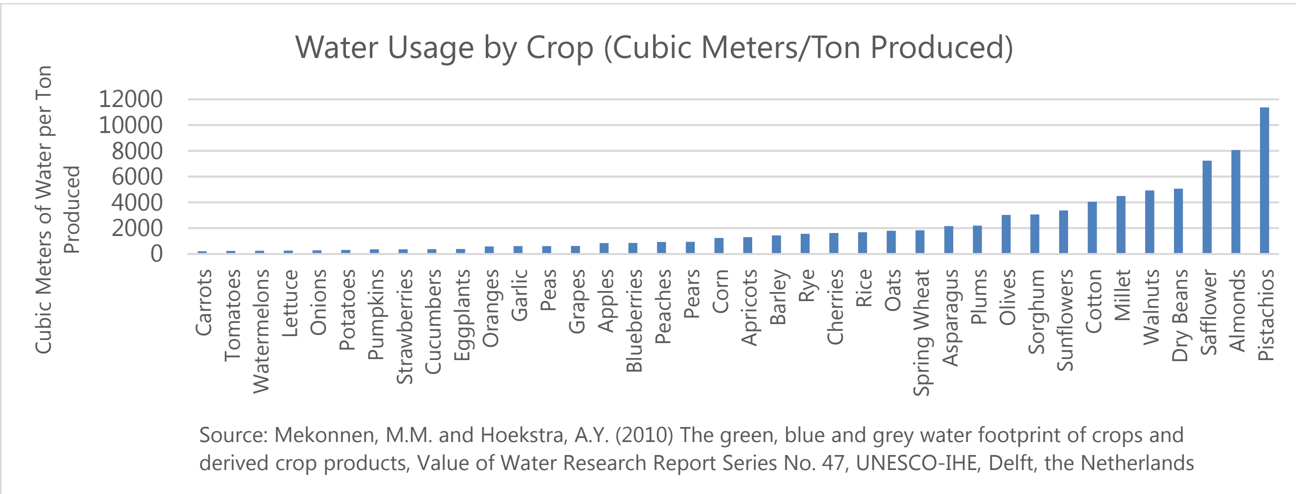


Figure 25. Water Usage by Crop (Cubic Meters/Ton Produced)

California agriculture depends on ground water for irrigation for sustenance in food production. The lack of precipitation not only impacts crop growth directly, but also groundwater levels must be replenished by annual precipitation. From 2005 to 2015, California statewide groundwater elevation levels decreased by 2%, while the California breadbasket, the Central Valley, saw declines of 19%.

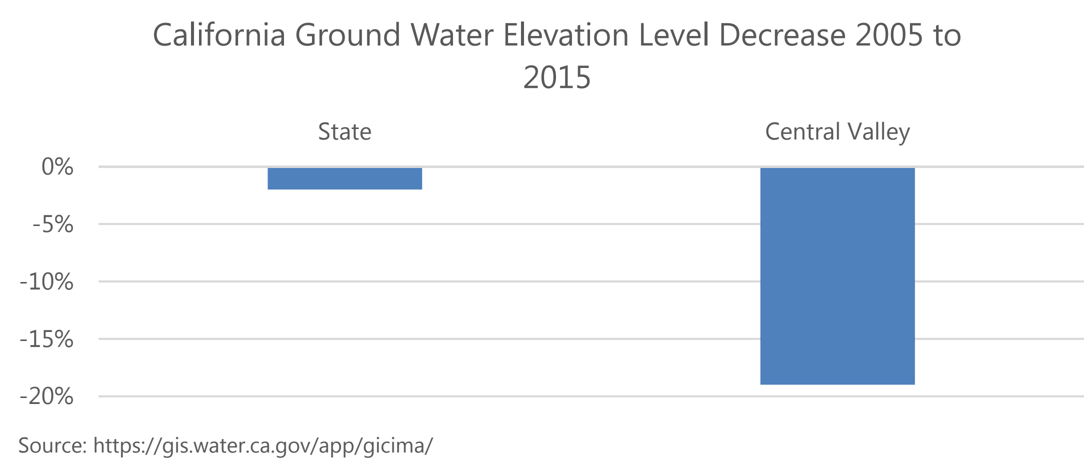
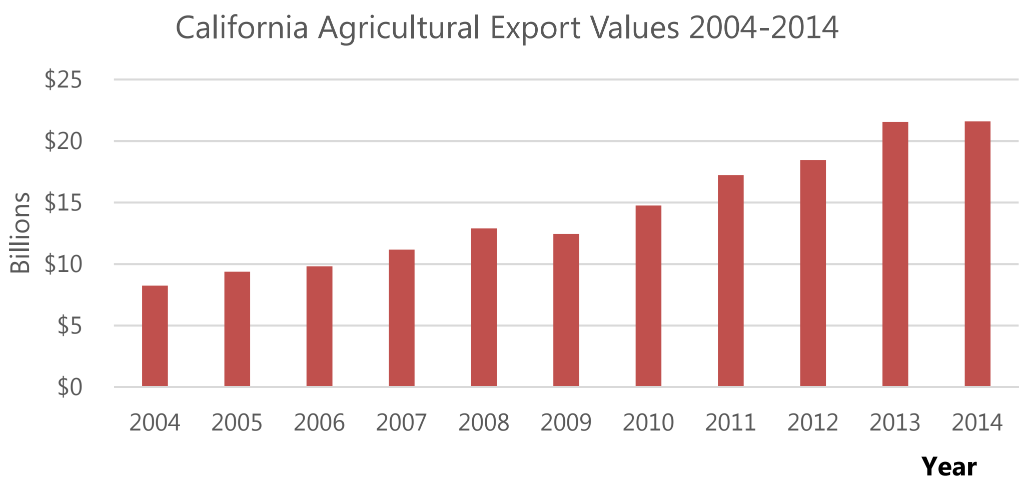


Figure 26. California Ground Water Elevation Level Decrease 2005 to 2015

The decreases in water availability may be linked to the plateauing production numbers even though harvested acres continue to increase. The drought impacts are only beginning to be felt, though.

Even with the significant pressure on the California agricultural sector, the state realized a significant increase in exports from 2004 to 2014. However, from 2013 to 2014, exports remained nearly flat, as shown in Figure 27.



Source: https://www.cdfa.ca.gov/Statistics/PDFs/AgExports2014-2015.pdf

Figure 27. California Agricultural Export Values 2004-2014

RELATED PERFORMANCE MEASURES

The impacts of this scenario will be measured by:

- Acres of harvested land
- Number of employees and establishment in NAICS 11, …
- Manufacturing GDP
- Population
- Employment
- Tonnage of agriculture , food and beverage production in each FAZ (Commodity group 1 and 7)
- Tonnage of agriculture , food and beverage and chemical and fertilizer products Consumed in each FAZ (Commodity group 1, 7, 2)
- Tonnage of agriculture , food and beverage imported to each FAZ (Commodity group 1 and 7)
- Tonnage of agriculture , food and beverage exported from each FAZ (Commodity group 1 and 7)
- Volume of trucks
- Speed of trucks
- GHG
- Percent of through versus local truck traffic in each county
- ….

FUTURE TRENDS AND MODEL IMPLICATIONS

To forecast the impacts of severe weather changes on freight transportation especially in regions with strong agriculture and farming industries, a number of assumptions and inputs based on the current context and accessible data have to be defined.

Based on our analysis, we expect that if the drought continues, there will be the following impacts by 2040 on California agriculture and related industries:

- Acres of harvested land will be reduced by 30% in the San Joaquin Valley relative to the base future scenario

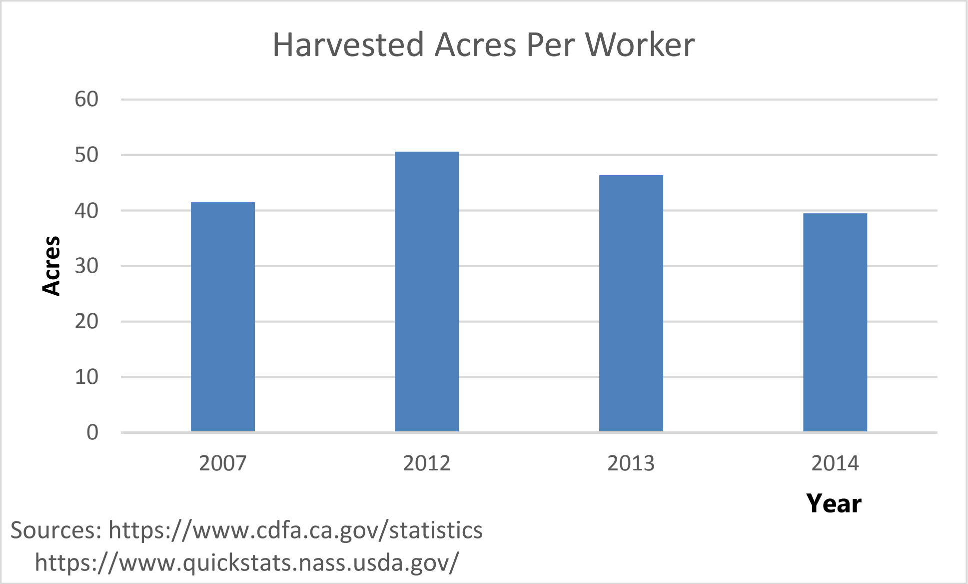


Figure 28. Harvested Acres per Worker

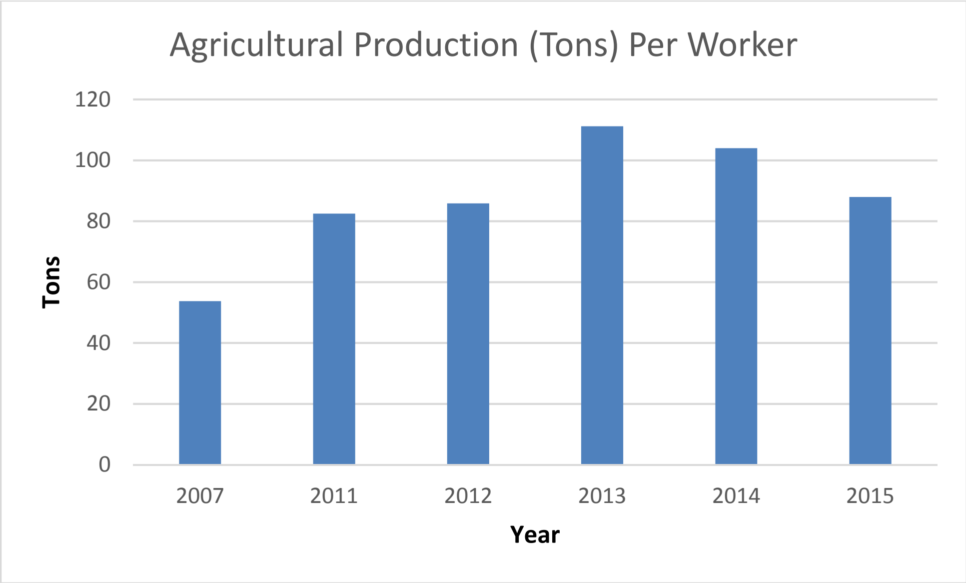


Figure 29. Agricultural Production (Tons) per Worker

The drought will cause shifts in population as agricultural and manufacturing workers move to other areas with greater job opportunities. The model assumes this migration will happen at a greater pace in the rural areas of California than in the urban areas because rural areas are more dependent on agriculture industries. Thus, for every 44 acres of decrease in harvested acres, one agricultural worker will seek employment in a different region (FAZ) in California. Similarly, the average agricultural production per worker is 94 tons. Thus, for every decrease of 94 tons, one worker will seek employment in another region. The model assumes a higher-weighted flow from the rural areas to the urban areas in this drought scenario.

MODE SHIFT: RAIL IMPROVEMENT

Rail is efficient at moving heavy freight over long distances, as are water and pipeline freight services. Trucks excel in providing time-sensitive delivery services for high-value goods being transported over medium- and short-haul distances. Raw materials and heavy freight going long distances are likely to continue their journey by rail, or some combination of truck, rail, and water. With the future growth in freight, it is anticipated that freight rail will continue to make investments in the capacity required to move heavy and long-distance shipments.[14]

The majority of consumer commodities can be shipped by rail. Each person in the U.S. requires the movement of approximately 40 tons of freight every year. Many of the goods people use daily are either wholly shipped or contain components shipped by rail. 91% of rail freight is bulk commodities, such as agriculture and energy products, automobiles and components, construction materials, chemicals, coal, equipment, food, metals, minerals, and paper and pulp. The remaining 9% is intermodal traffic, which generally consists of consumer goods and other miscellaneous products.[15]

The California State Rail Plan (2008) identified several local “choke points” on the systems that should be addressed to provide for the increased volumes of traffic, such as Union Pacific’s (UP) Martinez Subdivision between Oakland and Martinez or UP’s Tehachapi Pass line between Bakersfield and Mojave. However, the level of detail in the model does not allow for the measurement of local improvements. In CSFFM 2.0, the rail cost function is based only on Distance and handling cost at intermodal facilities and a series of fixed dummies coefficients for each origin or destination. The actual travel time is not included due to lack of information about train schedules. To evaluate the sensitivity and performance of CSFFM in reflecting future improvements in the rail network, we developed a hypothetical scenario. In this scenario, the BNSF corridor in San Bernardino County will be improved to have more capacity and shorter travel time. This corridor is currently 280 miles. To reflect this improvement, we assume that the length of the corridor will be reduced by about 30% to 200 miles. This is the direct distance between from Ontario to the eastern border of San Bernardino County, as shown in Figure 30. This change does NOT mean that the travel time or capacity on this rail corridor has improved by 30%. The objective is to evaluate the sensitivity of the model. For CSFFM 3.00 we will improve the rail and truck mode split module.

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[14] Federal Railroad Administration, "National Rail Plan Progress Report", September 2010.
[15] Association of American Railroads, “Class I Railroad Statistics”, May 2012.

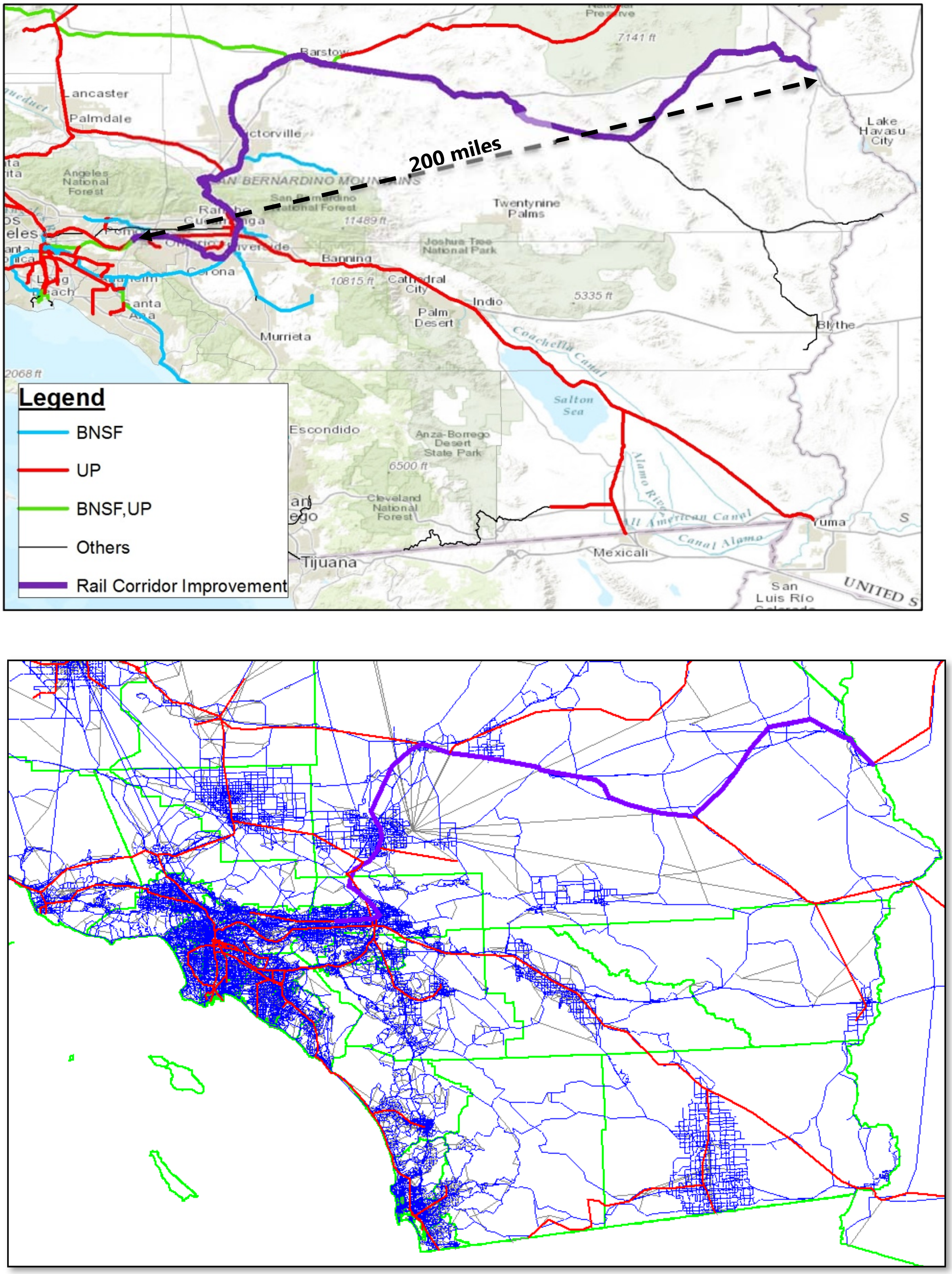

Figure 30. Rail Improvements Scenario

To measure the impacts of this improvement, the following metrics are estimated and compared with the base (2012) scenario:

- Border crossing truck traffic: near California border on I-10, I-40 and I-15
- Regional truck traffic: in Long Beach area on I-710, I-405 and SR-91 east of I-710
- Truck tonnage: between San Pedro Bay Area and other regions
- Rail tonnage: between San Pedro Bay Area and other regions

We assume that all industries will benefit from this improvement equally.

Expectations:

- Overall truck volume will be decreased, especially along east/west corridors in southern California.
- Overall truck tonnage flows will be decreased, especially from/to southern California
- Overall rail tonnage flows will be increase, especially from/to southern California

Questions:

- Is the magnitude of the volume shift from truck to rail reasonable?
- What is the geographic scale of impacts of this improvement? Only on Southern California? Entire state?
- What are the areas that truck volume significantly increased?
- The volume related to which class of trucks got impacted the most?

Figure 31 and Figure 32 show the difference plot: the difference between truck volume in base scenario and Rail Improvement Scenario. Red bands show negative growth larger than 25 trucks.

As shown in Figure 31 the impacts of this rail improvement project reduce truck traffic on nationwide east/west corridor. More cargo will be transported by rail from the ports of Los Angeles and Long Beach to the East Coast. Table 6 shows that the shift between truck only and multi modal (truck and rail) is about 650 Ktons per day. This is an interesting and complicated impact, showing how both modes are integrated.

Table 6. Comparison of O/D Table with Base Scenario

Mode	Scenario	Base	Difference	% change
Truck Only	8,867,283	8,867,931	(648)	-0.01%
Rail Only	624,214	624,227	(13)	0.00%
Rail-Truck	295,054	294,393	661	0.22%
Sum Ktons	9,786,551	9,786,551	-	0.00%

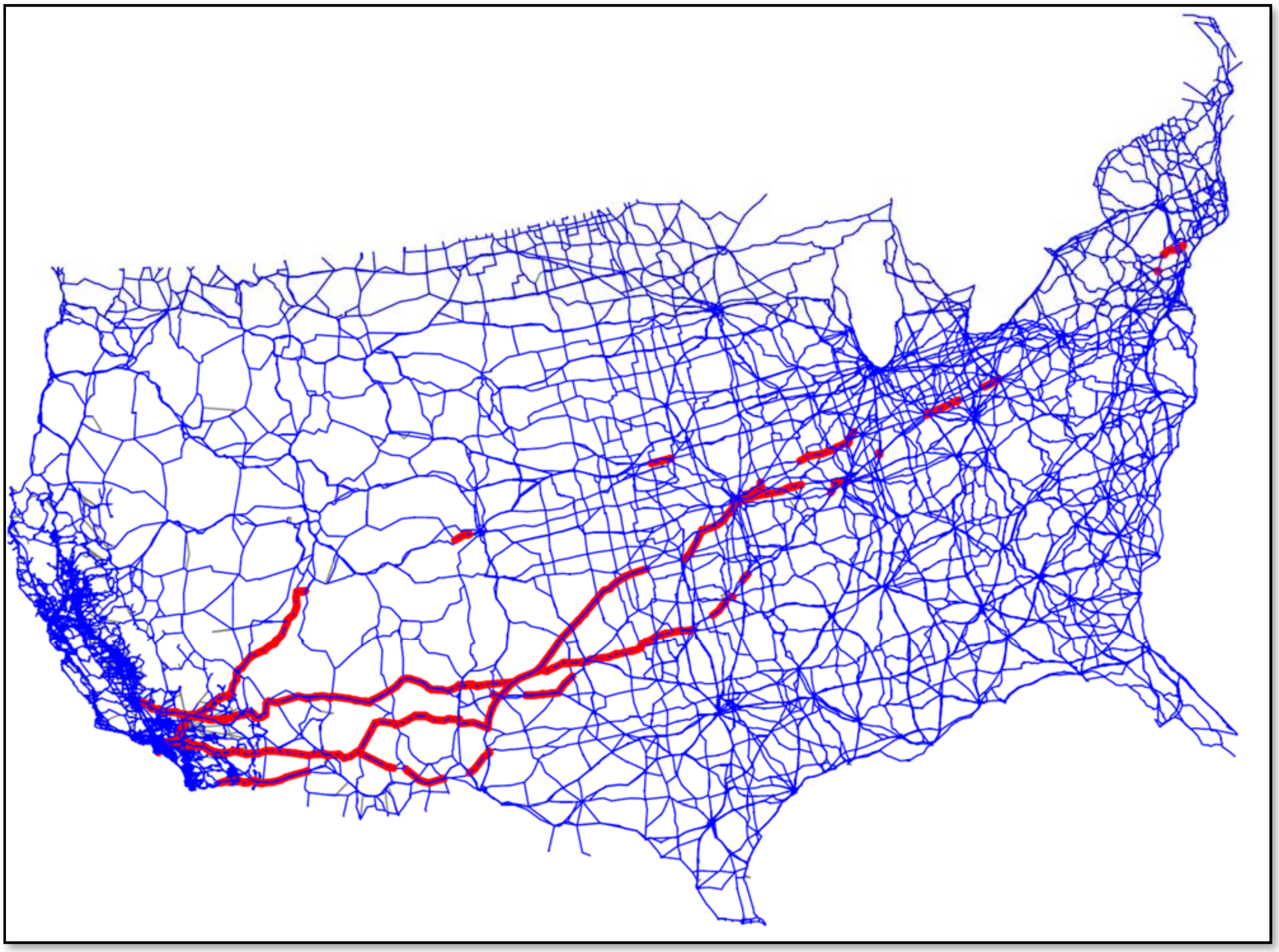

Figure 31. Comparison of Total Truck Volume with Base Truck Volume- National

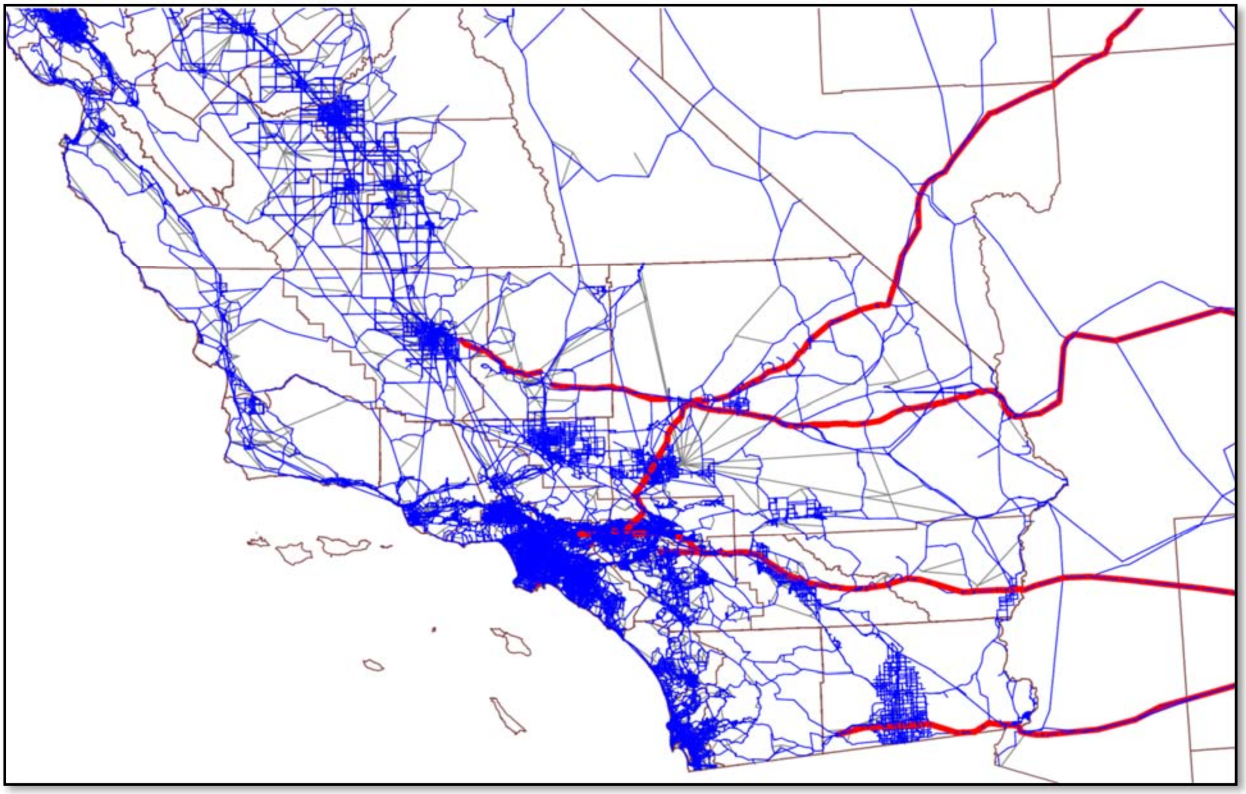

Figure 32. Comparison of Total Truck Volume with Base Truck Volume- Southern California