Matrix Estimation as a Calibration Tool in Commercial Vehicle Modeling

Michelle Bina
Cambridge Systematics, Inc.
Oakland, CA
Email: mbina@camsys.com

Rachel Copperman
Cambridge Systematics, Inc.
Austin, TX
Email: rcopperman@camsys.com

Ronald West
Cambridge Systematics, Inc.
Oakland, CA
Email: rwest@camsys.com

Daniel Beagan
Cambridge Systematics, Inc.
Cambridge, CA
Email: dbeagan@camsys.com

To be Presented at the 3rd Conference on Innovations in Travel Modeling
May 2010, Tempe, Arizona

Abstract

While matrix estimation is a standard process employed in many transportation studies and analyses, the process is used here to assist in model development and guide calibration efforts for a freight component within an existing travel demand model. Utilizing origin-destination matrix estimation (ODME) to create an observed truck trip table, with observed truck counts as constraints, the seeded and ODME-estimated matrices were compared to identify where the existing model was not replicating trips accurately. Trip generation rates were modified to reflect the percent change between the ODME-estimated and existing model trip tables for those origin-destination (O-D) pairs that were adjusted during the ODME process. Furthermore, trip distribution parameters (friction factors and highway skims) were adjusted to better match trip length frequency distributions of the ODME-estimated assigned truck trips. Use of the matrix estimated O-D trip table has led to significantly improved validation statistics, reducing the percent error for total truck trips from -57% in the existing model to -3% after trip generation and distribution modifications based on ODME adjustments, as well as expediting the calibration process.

Keywords: ODME, commercial vehicles, freight modeling

Introduction

The Alameda County Congestion Management Agency (ACCMA), located in the San Francisco Bay Area, addresses transportation needs by coordinating planning efforts, funding, and other such transportation activities. Alameda County represents an urban area that faces increasing congestion on many transportation facilities. Cambridge Systematics, Inc. has led efforts to update ACCMA's travel demand model by including an improved freight model component. The enhanced model will improve ACCMA efforts to model truck impacts within the region.

Methodology

Initial focus of this work has been on improving the freight truck component of the 2005 Alameda Countywide Transportation Model for the daily time period, though future work will include model development for other time periods. Extensive data collection efforts, review of the existing model, an origin-destination matrix estimation, and revised trip generation and distribution are the basis of the model update.

Data Collection

For the purposes of validation, a extensive database of observed truck counts was needed for evaluating the existing model and improvements to the model. New count data were collected at one dozen highway locations and at 50 arterial locations. In addition, Performance Measurement System (PeMS) data were examined throughout Alameda County, with an emphasis on including locations where new data was collected. Caltrans Traffic Count Book and Truck AADT reports were also consulted, especially for locations outside of Alameda County along major truck routes. Newly collected data, PeMS data, and Caltrans data, adjusted when needed to reflect 2005 conditions, were combined to create a database of information to be used for both model development as well as model validation.

Review of Existing Model

Trip generation estimates productions and attractions for each of the truck types (very small [2-axle, 4 tires], small [2-axle, 6 tires], medium [3-axle], and combo [4-axle +]) separately, and the gravity model is used to distribute productions and attractions between zones for each truck type. However, all model steps after trip distribution are performed with the four truck classifications aggregated to total trucks. Therefore, the final loaded network did not distinguish between truck type and only contained four vehicle types (drive alone, shared ride [2 persons], shared ride [3 or more persons], and truck). The model script was modified to maintain separate truck classes through the assignment stage in order to evaluate the model's performance.

Analyses from previous truck modeling studies[i,ii] confirm that the ability to accurately predict truck volumes in the lighter weight categories, which are mostly standard pickups and vans, is one of the most serious short-comings in an urban truck model. These trucks are considered to be "very small" trucks or FHWA Class 3 vehicles in the current ACCMA truck model. Many of these trucks are used as personal vehicles and thus, are already captured in the ACCMA passenger travel model. It is extremely difficult, if not impossible, when conducting vehicle classification counts to distinguish the commercial use vehicles from the personal use vehicles which fall under FHWA Class 3. This leads to poor results when validating the truck model for Class 3 vehicles. For this freight model, "very small" trucks was be modeled in the passenger travel modeling framework but excluded from the truck modeling framework.

A basic visual evaluation of assigned total truck trips from the existing model reveal zero truck trips at external stations, as well as underestimated volumes on major truck corridors outside of Alameda County. This major short-coming was identified as a key element to be added to the developing freight model.

Origin-Destination Matrix Estimation

The ODME procedure is an accepted practice that estimates trip tables based on traffic count data. Input data includes observed traffic counts on each directional link and the existing passenger travel model O-D trip table (used as a seed matrix). Using the seed matrix and observed volumes as control totals, the ODME process is executed within the chosen estimator (in this case, Cube Analyst) to estimate an O-D trip table which, when assigned to the network, produces link flows that optimally match the observed counts.

Cube Analyst requires a seed matrix to begin the estimation process, in order to identify which cells to adjust. A key limitation of Cube Analyst is that it only optimizes one trip table, based on one set of counts; whereas, in reality, there are multiple vehicle classes for which the assigned trips would ideally be validated. Standard industry practice has been to use total trips as the seed matrix, calculate an ODME-adjustment ratio matrix (of the estimated matrix to the seed matrix) for each O-D pair and apply the ratios to the O-D tables for each vehicle class.

The assumption that adjustments are the same for each vehicle class is not appropriate while developing a truck model within a validated passenger travel model for which the objective is to address truck trips, not auto trips. To overcome this problem, the existing model's O-D table for total truck trips was used as the seed matrix, observed total truck trips were the constraint, and the existing model's assigned auto trips (drive alone and shared-ride) were preloaded to the network. Additionally, the existing model's O-D table for truck trips was modified to account for previously unassigned external zones by adding nonzero values to cells that represent those zones as an origin or a destination, in order for those cells to be adjusted during the ODME process. The resultant estimated trip table provides the most probable adjusted truck trips for each O-D pair, which can then be assigned to the network. Not only were the assigned trips from the ODME-adjusted trip table used during validation as a baseline but also aided the calibration efforts for the trip generation and trip distribution phases.

Model Results

Assigned model volumes were used as a validation check by comparing summary statistics for each identified network link with observed counts within Alameda County. The following performance measures were used for validation purposes:

- Percent difference between model volumes and observed counts (or percent error).
- Percent root mean square error (RMSE). This is an aggregate measure of all links, whereas the difference measure above can be based on individual links.
- Overall goodness of fit measure (R-squared) for the assigned total volumes.

R-squared and RMSE values are based on standards developed from the FHWA Travel Model Validation and Reasonableness Checking Manual and from the Travel Model Improvement Program White Paper on Model Validation[iii]. The area wide acceptable and preferred targets for percent RMSE are +/-45% and +/-35%, respectively. Furthermore, trip length frequency distributions were evaluated as a validation check for the trip distribution phase, using ODME-adjusted assigned trips as the most-likely observed truck trip length distribution.

Existing Model

Existing Model Validation

The results of the existing 2005 ACCMA model's daily assigned trips were compared to the observed counts. It should be noted that, while traffic counts inside and outside of Alameda County are used in the ODME process, the validation statistics reported here are only for roadways in Alameda County. Table 1 provides validation statistics for the overall model and by vehicle class. As expected, the assigned total vehicles and auto trips meet the acceptable target for percent RMSE.

Table 1 – Existing ACCMA Model Validation Summary Statistics

Performance Measure	Total Vehicles	Autos	Total Trucks	Small Trucks	Medium Trucks	Combo Trucks
Sum of Observed Volumes	3,405,986	3,084,157	321,828	69,594	76,525	175,710
Sum of Modeled Volumes	2,992,611	2,731,870	139,385	5,447	25,150	108,788
Percent Error	-12%	-11%	-57%	-92%	-67%	-38%
Percent RMSE	41%	38%	147%	132%	164%	164%
R-squared	0.88					

ODME Results

ODME Estimated Trip Table

The ODME process resulted in an estimated O-D trip table for total truck trips. A ratio matrix was calculated in order to examine the adjustments from ODME. Isolating the ratio matrix for internal-to-internal (I-I) zone pairs, the overall adjustment was a decrease of 5%, suggesting fairly accurate trip generation and distribution for I-I trips. However, the trip table total increased by 36%, due to internal-to-external/external-to-internal (IE/EI) and external-to-external (E-E) truck trips that were not previously included in the original model .

Trip Generation Calibration

The original trip generation rates include different rates for production and attractions as well as separated rates for garaged and non-garaged truck trips, for the three truck types discussed previously. These rates included coefficients which were applied to zonal employment in six different categories: Manufacturing, Retail, Service, Other, Wholesale, and Agriculture. Conceptually, it did not make sense for production and attraction rates to be different on a daily basis. While garage trips would be useful if the model included truck chaining, which it does not, separating these rates served no purpose. The production and attraction rates were averaged to provide a new starting point for the truck trip rates, which were applied only to I-I trips.

The trip table cells which were changed during the ODME process were compared with those same cells in the original table. A ratio of the sum of the changes was calculated for I-I trips. While there are different rates by employment type and truck type, an assumption was made that since no additional information was available, the ratio could be applied to adjust all trip generation rates.

While trip generation rates did not previously exist for IE/EI productions and attractions, initial IE/EI trip generation rates were obtained from another regional transportation agency, Santa Clara Valley Transportation Authority (VTA), who have a freight travel mode that separates I-I and IE/EI trip generation and distribution. Additionally, special generator truck productions and attractions were developed for the Port of Oakland based on observed truck counts near the port.

The application of ratios to the trip generation rates was done iteratively along with adjustments to the trip distribution and assignment steps described in sections below.

Trip Distribution Calibration

Trip Length Frequency Distributions (TLFD) were prepared and examined for the original and the ODME tables. A comparison of these distributions guided not only changes to the friction factors, but also changes to the use of impedance variables. Examples of changes to the TLFD for IE/EI and I-I truck trips can be seen in Figures 2 and 3. The existing model TLFD used the AM skim times, which were the impedances used in the auto distribution, and differed considerably from the distribution of the ODME adjusted table for IE/EI trips. When the off peak skims were used as the impedance variable, as well as changes to the friction factors, the

TLFD more closely matched that of the ODME table. While the adjustment was not as dramatic for other trip types, the ODME table was used to determine what changes should be made to the trip distribution process.

Figure 2 – Trip Length Frequency Distribution for IE/EI Small Truck Trips

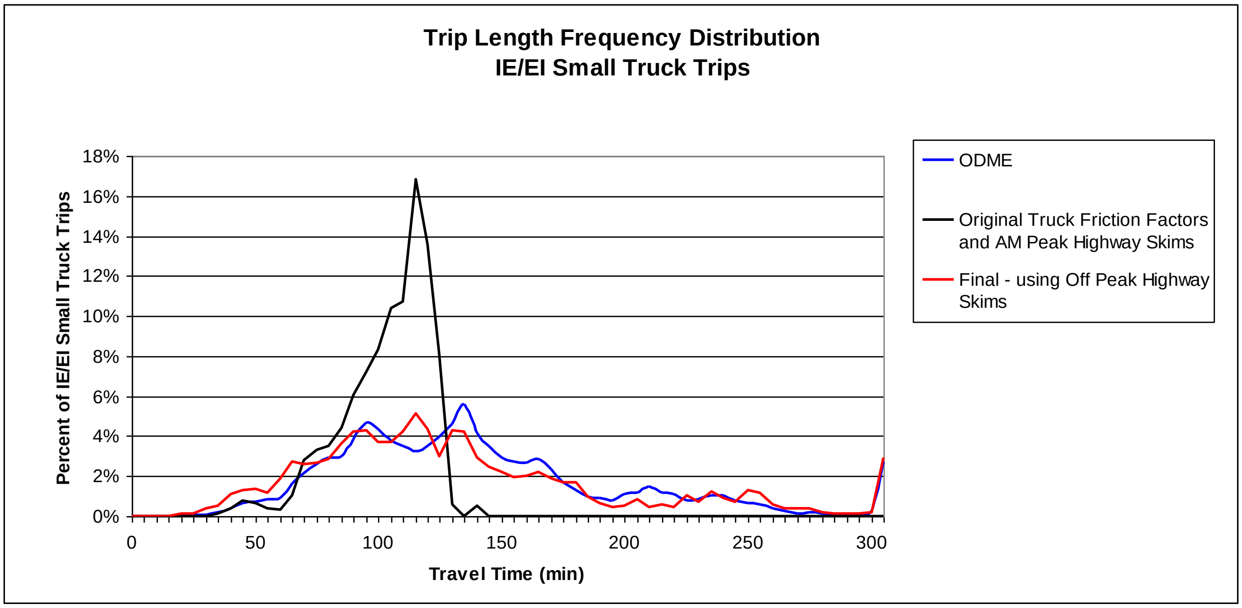
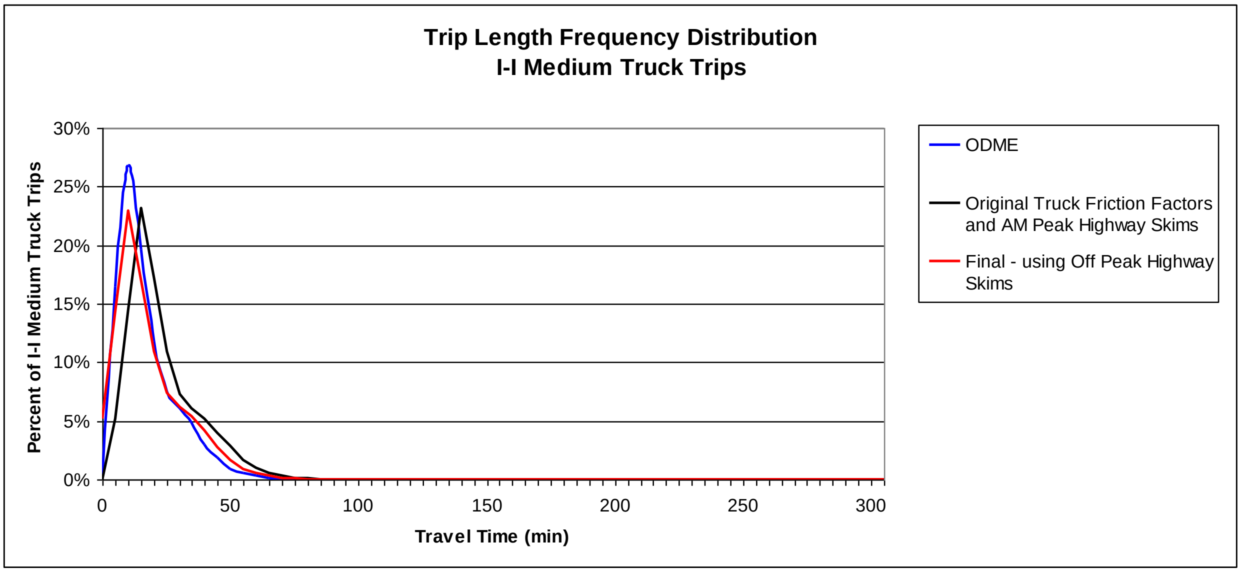


Figure 3 – Trip Length Frequency Distribution for I-I Medium Truck Trips



Trip Assignment

While not actually an adjustment which was guided by the ODME, the original model's assignment was executed in terms of vehicles and the link capacities were expressed in terms of vehicles per hour, with a truck being one vehicle. An improvement was made by applying a Passenger Car Equivalent (PCE), factors of 1.5 for medium trucks and 2.0 for combo trucks, to the truck tables and expressing the link capacities in terms of passenger cars per hour. This was done in a multi-class assignment with autos, which changed the assignment of all vehicles.

ODME Validation

Table 4 provides validation statistics for the latest model results post trip generation and distribution adjustments that were guided by the ODME trip table. These calibration efforts yielded an overall 54% decrease in error and 55% decrease in RMSE for total trucks.

Table 4 – Final Model Validation Summary Statistics

Performance Measure	Total Vehicles	Autos	Total Trucks	Small Trucks	Medium Trucks	Combo Trucks
Sum of Observed Volumes	3,405,986	3,084,157	321,828	69,594	76,525	175,710
Sum of Modeled Volumes	3,827,089	3,302,397	312,602	66,136	68,774	177,692
Percent Error	12%	7%	-3%	-5%	-10%	1%
Percent RMSE	42%	35%	92%	146%	123%	92%
R-squared	0.87					

Conclusions and Extensions

The ODME trip table, which could readily be prepared from the original truck tables and validation counts, proved invaluable in guiding the enhancements to the ACCMA truck model. It was used to suggest the inclusion of external trucks and Port special generator trucks, to develop adjustment factors to be applied to the trip generation rates, and to suggest alternative impedance skims and new friction factors for the trip distribution process. These changes were enhanced by the use of PCEs for truck trips during the assignment process. The availability of an ODME-derived truck table as guidance during calibration greatly expedited the process.

The model update is still an ongoing process. Future work will include a more extensive look at the trip assignment step and PCE capacities. ODME will also be utilized while calibrating the freight model for other time periods.

References

[i] Meyer Mohaddes Associates, *SCAG Heavy Duty Truck (HDT) Model*, prepared for Southern California Association of Governments, 1999.

[ii] Cambridge Systematics, Inc., *SCAG Truck Count Study: Truck Classification System*, prepared for Southern California Association of Governments, August 2001.

[iii] National Cooperative Highway Research Program Report 255, Calibration and Adjustment of System Planning Models, 1990.

Travel Model Improvement Program, Federal Highway Administration, Model Validation and Reasonableness Checking Manual, 1997.

Travel Model Improvement Program, Federal Highway Administration, Travel Model Validation Practice Peer Exchange White Paper, December 3, 2008