CAMBRIDGE SYSTEMATICS

TxLED VMT Estimation Project

final report

prepared for

Texas Commission on Environmental Quality

prepared by

Cambridge Systematics, Inc.

with

Eastern Research Group, Inc.
Alliance-Transportation Group, Inc.

August 2004

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Executive Summary

The Texas Commission of Environmental Quality (TCEQ) is in the process of evaluating the potential effectiveness of the Texas Low-emission diesel fuel (TxLED) program. TxLED is a low sulfur fuel designed to reduce emissions from diesel vehicles. The purpose of this project was to estimate consumption of this fuel for the on-road truck fleet in the Dallas and Houston metropolitan areas. The methodology prescribed for this estimate relied on several separate data sources.

The general methodology for estimating truck VMT for each of the truck trip types is developed using the simple formula expressed in the following equation:

Total Truck VMT = (Pass-Through Truck VMT) + ("I-X/X-I" Truck VMT) + (Internal Truck VMT).

"I-X/X-I" VMT denotes internal-to-external trips plus external-to-internal trips and refers to truck trips with one trip end inside a major metropolitan area and one trip end outside a major metropolitan area.

The project was performed through separate tasks as follows:

- Develop estimate of total truck VMT - Total truck VMT was calculated using existing truck counts that are submitted by the Texas Department of Transportation to the Federal Highway Administration
- Coordination with stakeholders – The consultant team held discussions with TxDOT, and the metropolitan planning organizations for the Dallas and Houston metropolitan areas to understand the methodologies for developing the truck portions of their respective travel demand models.
- Develop Data Integration Plan - A data integration plan was developed based on comparing each of the relevant data sources and determining which combination of data would generate the best set of truck VMT estimates.
- Tasks are designed to develop estimates of pass-through, internal-external/external-internal, and internal truck VMT. For each task (and corresponding truck trip type), it was determined that the truck VMT would be estimated based on the percentage of each truck trip type in the SAM multiplied by the total truck VMT estimated in Task 1.
- Write report – This document represents the final report for the project.

These tasks generated truck VMT estimates by tri type for the Dallas and Houston metropolitan areas for 1998 (Table ES-1). Truck trips were found to be somewhat different in each of the two metropolitan areas. Through truck trips in Dallas are 29 percent compared to just 10 percent in the Houston region. These truck trips are the least likely to be fueled inside the state, and therefore the least

likely to use TxLED fuel. This factor was balanced by the higher percentage of single-unit trucks in Dallas relative to Houston. Single-unit trucks are less likely to use TxLED than combination trucks, because 41 percent of these trucks are estimated to be fueled using gasoline rather than diesel. These two factors roughly balanced each other out so that the percent of VMT using TxLED fuel in each of these regions was very similar, 69 percent for Dallas and 67 percent for Houston.

Table ES-1 Final VMT Estimates by Trip Type (1998)

Trip Type	Dallas Metro Area	Percent of Total	Houston Metro Area	Percent of Total
Total	9,987,663	100%	8,055,634	100%
Through	2,858,798	29%	817,392	10%
I-X	1,693,182	17%	2,562,167	32%
X-I	1,943,729	19%	2,222,641	28%
Internal	3,491,955	35%	2,453,434	30%

Truck VMT estimates for 2002, 2007, 2010 and 2020 were also generated and can be found in the main body of the report.

This project went beyond the original scope by developing estimates of TxLED usage for each of the truck trip types and for total truck VMT in the region. Fuel type percentages were developed using the Vehicle Inventory and Use Survey for Texas. A roadside truck survey was used to develop estimates of TxLED fuel usage for each of nine truck trip types assuming TxLED was available throughout the state. This process generated the estimates for TxLED usage as shown in Table ES-2.

Table ES-2 TxLED Usage for Each Metropolitan Area

Trip Type ID	Total Truck VMT	Truck VMT Using TxLED	TxLED Usage
Dallas	9,987,663	6,860,915	69%
Houston	8,055,634	5,416,745	67%

These are relatively high usage rates for TxLED fuel indicating that implementation of that fuel throughout the state would indeed reduce diesel engine emissions. Freight flow data were also used to estimate the primary origins and destinations for truck flows in Texas. It shows that roughly 71 percent of the truck trips have origins or destinations in just 15 of the state's 254 counties. This indicates that a rollout of the TxLED program would be most effective by focusing on implementation in these 15 counties. The results of the study can be used to improve on-road emissions modeling by providing estimates of the impact of statewide fuel programs on actual truck activity. Estimating truck activity is the first step in truck emissions modeling.

While all of the truck trip types are forecast to exhibit a significant amount of VMT growth, the forecast of pass-through VMT is growing the slowest.

Therefore, the effectiveness of a statewide fuel program will increase in future years. Therefore, the ability of the state to handle future demand for freight service will increase in future years because a higher percentage of the truck trips will have origins and destinations entirely inside the state's jurisdiction. However, there is still roughly 30 percent of diesel truck VMT in each metropolitan area that is powered by fuel purchased outside of the state. Therefore, TCEQ should work with other states to implement low-sulfur fuel in the entire region.

The same methodology used in this study can be used in other metropolitan areas to determine the TxLED usage rates and TxLED VMT. The methodology can also be used to estimate TxLED usage for the entire state. One assumption that is incorporated into the current methodology is that TxLED fuel would be available throughout the state rather than the phased-in rollout that will occur for certain portions of the state. However, with additional resources, the methodology used for this analysis could be extended to develop TxLED usage rates based on availability for a specific set of counties within the state. An extension of this methodology can also be used to determine the impact of other states implementing TxLED or other similar fuel programs.

1.0 Introduction

The Texas Commission of Environmental Quality (TCEQ) is in the process of evaluating the potential effectiveness of the Texas Low-emission diesel fuel (TxLED) program. TxLED is a diesel fuel that is refined to have a lower sulfur content, a lower aromatic hydrocarbon content, and a higher cetane number than conventional diesel fuel. It also reduces the emissions of oxides of nitrogen (NOx) and other ozone-forming emissions. TCEQ hopes that increased use of TxLED will lead to reductions in diesel emissions throughout the State. This is of particular concern for the Dallas and Houston metropolitan areas because of the combination of high emissions and high truck volumes in those regions.

The TxLED Program requires that TxLED be sold or supplied year-round for use in all diesel fueled compression-ignition engines in on-road vehicles and in non-road equipment operating within 110 affected counties in central and eastern Texas. The TxLED Program, which begins April 1, 2005, limits all diesel fuel sold or supplied for use in on-road vehicles and in nonroad equipment in the affected 110-county region, to a maximum sulfur content of 500 parts per million (ppm), a maximum aromatic hydrocarbons content of 10 percent, and a minimum cetane number of 48. Diesel fuel formulations that have been approved for use in California or that has been approved by the TCEQ as providing equivalent emission reduction performance may also be used. Beginning June 1, 2006, the maximum sulfur content of TxLED used in both on-road vehicles and nonroad equipment in the affected 110-county region will be reduced to 15 ppm. The following is a list of the areas required to use TxLED in on-road vehicles and in nonroad equipment and that will be required in 2006 to use TxLED with a maximum sulfur content of 15 ppm in both on-road vehicles and in nonroad equipment:

- The Dallas-Fort Worth ozone nonattainment area of Collin, Dallas, Denton, and Tarrant Counties;
- The Houston-Galveston ozone nonattainment area of Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties;
- The Beaumont-Port Arthur ozone nonattainment area of Hardin, Jefferson, and Orange Counties; and
- The Counties of Anderson, Angelina, Aransas, Atascosa, Austin, Bastrop, Bee, Bell, Bexar, Bosque, Bowie, Brazos, Burleson, Caldwell, Calhoun, Camp, Cass, Cherokee, Colorado, Comal, Cooke, Coryell, De Witt, Delta, Ellis, Falls, Fannin, Fayette, Franklin, Freestone, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Harrison, Hays, Henderson, Hill, Hood, Hopkins, Houston, Hunt, Jackson, Jasper, Johnson, Karnes, Kaufman, Lamar, Lavaca, Lee, Leon, Limestone, Live Oak, Madison, Marion, Matagorda, McLennan, Milam, Morris, Nacogdoches, Navarro, Newton, Nueces, Panola, Parker,

Polk, Rains, Red River, Refugio, Robertson, Rockwall, Rusk, Sabine, San Jacinto, San Patricio, San Augustine, Shelby, Smith, Somervell, Titus, Travis, Trinity, Tyler, Upshur, Van Zandt, Victoria, Walker, Washington, Wharton, Williamson, Wilson, Wise, and Wood.

These state regulations affect diesel fuel suppliers that produce fuel for and/or import fuel into the State. Fuel suppliers that do not produce fuel and do not import fuel from outside the State but only distribute fuel within the affected areas and are not responsible for any fuel composition changes are not required to register. However, all fuel suppliers that import fuel into the State are required to register and are required to comply with all other aspects of these regulations.

Estimating the participation rate of the on-road vehicle fleet in the TxLED program is an important part of understanding the impact of the TxLED program on statewide emissions. This participation rate is impacted by two primary factors: 1) the percentage of trucks that are fueled within the State of Texas and 2) the percentage of trucks that use diesel rather than gas. However, the large operating range of trucks often includes movements among multiple states. This complicates the process of matching truck trips and fuel consumption. The presence of both diesel and gasoline trucks further complicates the estimation of TxLED usage in the on-road truck fleet.

Developing estimates of vehicle miles of travel (VMT) for different truck types is the first step in the process of estimating participation of trucks in the TxLED program. Truck trip types can be categorized as pass-through (X-X) trips, internal-external (I-X) trips, external-internal (X-I) trips, and internal trips. Truck trips that pass-through the metropolitan areas are the least likely to use the new diesel fuel. Truck trips with one trip end inside a metropolitan area have a slightly higher likelihood of using the new diesel fuel. Truck trips with both trip ends inside a major metropolitan area are the most likely to use the new diesel fuel. The scope of work for this task specifically focuses on developing these VMT estimates for the Houston and Dallas metropolitan areas. However, the methodology described in Section 2.0 can also be applied to other metropolitan areas in Texas.

2.0 General Methodology

The methodology for estimating truck VMT for each of the truck trip types is developed using the simple formula expressed in the following equation:

Total Truck VMT = (Pass-Through Truck VMT) + ("I-X/X-I" Truck VMT) + (Internal Truck VMT).

"I-X/X-I" VMT denotes internal-to-external trips plus external-to-internal trips and refers to truck trips with one trip end inside a major metropolitan area and one trip end outside a major metropolitan area. There are four primary data sources for estimating truck VMT by each of these trip types:

1. The Texas Department of Transportation (TxDOT) Statewide Analysis Model (SAM);
2. TxDOT Highway Performance Monitoring System (HPMS) vehicle classification data;
3. Reebie TRANSEARCH freight flow data for State of Texas; and
4. Metropolitan-level travel models of Houston and Dallas.

Each of these data sources estimates the VMT of different truck trip types with varying levels of accuracy. The goal of this project is to develop the most accurate VMT estimates for each truck trip type using a combination of these sources. Additionally, estimates of how VMT usage may translate into TxLED program impacts were made using two additional truck data sources: the Bureau of Census Vehicle Inventory and Use Survey for the State of Texas and a truck travel survey performed at a weigh station outside of the Houston metropolitan area. The approach of this project divided the work into nine tasks as follows:

Task 1 – Develop Work Plan

A project Work Plan was developed and approved by the TCEQ.

Task 2 – Coordination with Stakeholders

The SAM and the metropolitan-level models are owned and operated by staff at the respective transportation agencies. The CS team worked with TxDOT, H-GAC, and NCTCOG to understand the methodologies for developing the truck portions of their transportation demand models and to develop the estimates for specific truck trip types.

Task 3 – Develop Data Integration Plan

A data integration plan was developed to examine the methodologies for each of the truck data sources and determine which elements represent the most ideal estimation process for the purposes of this project. Information gathered in

Task 2 along with the estimates developed in the other tasks was a primary source for these comparisons.

Task 4 – Develop Estimate of Total Truck VMT

Total truck VMT was calculated using existing truck counts in the State. The Federal Highway Administration (FHWA) Highway Performance Monitoring System (HPMS) mandates that each state DOT collect vehicle count data and estimate VMT for all vehicle classes on the state roadway system. Interpolation of the HPMS truck count data was used to develop estimates of the truck VMT on freeway networks.

Task 5 – Develop Estimate of Pass-Through VMT

The Statewide Analysis Model is ideal for estimating the proportion of total truck VMT that passes through the major metropolitan areas, because the model has higher accuracy for long-range relative to short-range truck trips. For each metropolitan area, truck trips with both trip ends outside of the metropolitan area were separated from the larger truck trip table. The remaining truck trips were then routed on to the network using a shortest-distance path, all-or-nothing assignment. The resulting VMT inside the metropolitan area is then entirely from through trips.

Task 6 – Develop Estimate of Internal-External and External-Internal Truck VMT

Internal-external and external-internal (I-X/X-I) truck trips have one trip end inside a metropolitan area and the other trip end outside that area. Estimation of VMT for these truck trips was done in a similar fashion as the estimation process for pass-through trips. The I-X/X-I truck trips were extracted from the larger truck trip table in the SAM. These trips were then routed onto the statewide network using a shortest path, all-or-nothing assignment. To estimate VMT, the portion of each of the routed trip assignments inside the particular metropolitan area was calculated.

Task 7 – Develop Estimate of Internal VMT

The VMT for truck trips with both trip ends inside the study area was calculated using the SAM. The SAM develops many of its short-distance truck trips using a commercial vehicle trip model with trip generation rates based on the Quick Response Freight Manual, as discussed below.

Task 8 – Perform Origin-Destination Survey

An origin-destination survey was performed at a weigh station outside Houston to correlate trip type (internal, I-X, X-I and through) to location of fuel consumption (inside state or outside state). This survey was conducted on trucks traveling in both directions during a 24-hour time period.

Task 9 –Reporting

The last task in the study was the creation of this written report. This report describes the freight flow databases and models in Texas and the metropolitan areas of Dallas and Houston. This report also describes the components of each of the model outputs and other data that were used to generate VMT estimates. The base-year data for the VMT estimates is 2002 and the forecast years included in this report are 2007, 2010 and 2020. This report also includes a description of the process for estimating the VMT that will be driven using TxLED fuel.

This project generated the following files, which will also be made available to TCEQ:

1) HPMS data for Dallas and Houston

2) 24-hour truck count data for Dallas and Houston

3) Origin-destination data from truck roadside survey

3.0 Background on Existing Models

This section discusses the methodology used to develop the metropolitan-level models for Dallas and Houston and the TxDOT SAM. Descriptions are provided for the base-year formulations and the methodology for forecasting the travel model into future years.

3.1 DALLAS METROPOLITAN-LEVEL TRUCK MODEL

The North Central Texas Council of Governments (NCTCOG) is the MPO for the Dallas/Fort Worth region. NCTCOG consists of 16 counties, nine of which fall under the purview of this study. These nine counties of concern are: Dallas, Tarrant, Collin, Denton, Ellis, Parker, Johnson, Rockwell, and Kaufman. The NCTCOG travel demand model currently covers an area of about 5,000 square miles, but only five counties (Dallas, Tarrant, Collin, Denton, and Rockwall) are fully contained in the travel model area. All nine counties are now nonattainment for the eight-hour ozone standard. Therefore, efforts are being made to perform work that covers the portions of the nine counties in the currently non-modeled counties.

NCTCOG has a vehicle-based truck model for vehicles with six or more tires. These vehicles are all considered to be trucks in their model output and analyses. A work place survey was conducted in 1994 to develop trip rates for three truck types: retail, service, and basic. These surveys also collected time-of-day information for each of these truck trip types. NCTCOG used techniques described in the FHWA Quick Response Freight Manual (QRFM) to develop gravity model curves to distribute truck trips by type. Local truck counts, along with overall truck VMT from TX DOT permanent count locations, were also collected. The final model was then validated by adjusting the QRFM gravity model curve to fit the trip rates to the VMT.

Classification counts and VMT data were then used to validate the truck trip assignment for each time period (a multi-class assignment). (The model output was not compared to the SAM output because the SAM was formulated using freight flow rather than truck count data.) In order to estimate the vehicle classification split, the NCTCOG uses generic fleet-mix assumptions from the Texas Transportation Institute (TTI) to estimate the breakdown into light, medium, and heavy duty vehicles. Forecasts of the NCTCOG travel demand model are based on predictions of local socioeconomic factors such as households and employment. Therefore, the truck trips will increase proportionally to the three employment categories: retail, service, and other employment.

3.2 HOUSTON METROPOLITAN-LEVEL TRUCK MODEL

The Houston Galveston Area Council (H-GAC) serves as the MPO for transportation planning in the eight-county Houston-Galveston area. The MPO planning area includes Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. While the MPO has a travel demand model that is used for forecasting and planning, the MPO does not have a dedicated portion of its model to estimate truck activity. Truck activity is estimated using a post-processing technique whereby factors are applied to the model outputs based on count data in the region.

The H-GAC model estimates all vehicle trips based upon average trip rates for a given type of employment for each zone in the network. The model does include special generator estimates for ports, which it adds on to the above estimates. Ports are considered as special generators due to the large number of truck trips generated from these sources in the Houston area. These special generators include commercial airports and large commercial intermodal water ports. For the Houston area, Houston Hobby and Bush Intercontinental Airports, 15 different intermodal facilities and four different marine ports including the Port of Houston are considered to be special generators.

The trips for the commercial airports are estimated based upon a trip per enplanement rate, and forecast based upon enplanements provided by the City of Houston. For the intermodal water port facilities, estimates of the amount of truck traffic currently generated were derived from an Intermodal Facility Inventory study. A summary of the results from the HGAC Technical Memorandum of January 21, 2000 is presented in Table 3.1.

Table 3.1 Summary of Truck Trips Generated at Marine Ports in Houston Area

Facility	Trucks Per Day 2000	Forecasts		
		Trucks Per Day 2007	Trucks Per Day 2015	Trucks Per Day 2022
Port of Houston	1,379	3,586	5,478	10,572
Port of Galveston	77	155	244	300
Port of Freeport	350	424	508	582
Port of Texas City	0	0	2,250	3,000
Total	1,806	4,165	8,481	14,454

Source: http://www.h--gac.com/NR/rdonlyres/edkisvn64trwd23r22bztryvh3zqw72qv64gmen4jvriufeu2kjh5jrhrdc3cqoxecrtf4swep7wn52cbsaitquvomc/ConformityAppendixF.pdf.

The Texas Transportation Institute (TTI) develops vehicle classification splits for HGAC using a standard methodology used throughout the State, and VMT counts provided by TxDOT. The TTI methodology for converting the TxDOT counts is described in Section 3.2.1. HGAC uses the results from their travel

demand model on passenger movements and the VMT splits from TTI to perform emissions modeling.

Forecasts of the H-GAC travel demand model are based on proportionally increasing truck trips based on local socioeconomic data. Therefore truck trips are increased primarily based on employment and households for the metropolitan area.

3.2.1 TTI Methodology for Converting TxDOT Counts to VMT by Vehicle and Facility Type

TTI uses data from the H-GAC travel demand model and adjusts the model output to coalesce differences in the way roadways are categorized by the different models. This is done by creating a link between the model output and the FHWA functional class system.

In order to develop vehicle mix classifications TTI uses a slightly more complex procedure. The U.S. Environmental Protection Agency and MOBILE6 reporting requires a 28-class vehicle categorization based upon gross vehicle weight rating (GVWR) and fuel type. Data available from the travel model outputs and the most recent weekday vehicle classification counts use different classification schemes, which are converted into the FHWA classification scheme based upon vehicle length and number of axles.

The TTI methodology aggregates the FHWA classifications first into an intermediate grouping consisting of three sub-groups: 1) passenger vehicles, 2) heavy duty vehicles and 3) heavy-duty diesel vehicles with GVWR greater than 60,000 lbs (HDDV 8b), followed by a second intermediate allocation that separates light-duty vehicles into passenger cars and light-duty trucks based upon vehicle registration data from the State DOT. A third intermediate allocation is then done to further separate out light duty vehicles into their respective weight categories. The vehicle disaggregations are applied to the model outputs to develop VMT estimates allowing emissions estimates to be developed for each vehicle class in the region.

3.3 DESCRIPTION OF TXDOT STATEWIDE ANALYSIS MODEL

The Texas Statewide Analysis Model (SAM) is a transportation planning tool that provides base year (1998) and forecasted (2025) demographic and traffic patterns for the entire State. The program is TransCAD-based and mainly utilizes geographic files as its input data. These sources of data provide information for analysis of highway networks, intermodal facilities and traffic, intercity traffic, demographics, and for the purposes of this study, freight. The SAM model is comprised of 4,600 zones within Texas, as well as another 142 external zones, thereby creating a one-county buffer around the State. These zones contain input data for passenger and freight generation models. The SAM was not designed to

replace urban models, but to assist in the development of forecasting activities in non-urban areas. Therefore, the zone structure in urban areas is not as extensive as those of urban models. SAM Traffic Analysis Zones (TAZs) follow census block geography in rural areas, while in urban areas, MPO TAZs are aggregated.

The SAM utilizes 1998 Reebie TRANSEARCH commodity flow data for the primary commodity movements in the State. Reebie is a private vendor of commodity flow data. The commodity flow data purchased by TxDOT for the model include origin-destination (O-D) data by two-digit Standard Transportation Commodity Code for each county in the State. The commodity flow data were acquired for truck, rail, air, and water. The SAM model supplements the Reebie data with additional data to cover Mexican freight flows including data from Wharton Economic Forecasting Associates (WEFA) and the Latin America Trade Transportation Study (LATTS).

Reebie data are best suited for long-distance commodity movements. It is common for freight models that utilize Reebie data to supplement the freight flow data with short-distance truck trips based on local socioeconomic data. In the SAM, a second set of commercial vehicle trips are generated as part of the passenger model component utilizing a category called "OTH" with production and attraction rates based on the Quick Response Freight Manual. The commercial vehicles accounted for in the passenger model include both four-tire commercial vehicles that are purely passenger cars and single-unit trucks with six or more tires. The trucks generated in this component of the model are used to account for the short-distance truck trips not captured in the Reebie data.

3.3.1 Trip Generation

The freight trip generation models in the SAM are developed at the county level as Reebie data are organized with origins and destinations by county. As described previously, only primary commodity movements are accounted for in the freight model. The model, therefore, assumes that all of these trucks are combination vehicles.

Trip generation in the model utilizes regression equations that relate independent variables, including employment types and dummy variables representing special freight handling facilities, to tonnages produced or attracted for each county. Equations were developed in the SAM for the categories of Internal-Internal Productions, Internal-Internal Attractions, Internal-External Productions, and External-Internal Attractions. For each of these categories, different rates were generated for those counties above and below a population of less than 200,000. This provides an estimate of the freight growth associated with employment. An adjustment factor is applied to the initial control totals to account for worker productivity.

As mentioned previously, the commercial vehicle portion of the SAM generates truck trips based on local socioeconomic data.

3.3.2 Trip Distribution

Trip distribution is the process of matching trip productions with trip attractions. Trip distribution at the zone level in the SAM is performed by a gravity model that assumes the probability of trips between two locations is inversely related to the trip distance and directly related to the magnitude of activity at the destination. The SAM uses mathematical equations to replicate observed trip length distributions. Adjustment factors are also applied on a district-to-district basis to acceptably reproduce movements between subareas of the State. The SAM uses a standard software plug-in for trip distribution calculations. Friction factors were developed using standard factors extracted from TransCAD, a commonly-used transportation software. Additional information on trip distribution can be found in the SAM Theory Report[1] and the FHWA primer on trip distribution[2].

3.3.3 Mode Choice

The trip table generated from the Reebie data in the SAM can be assigned either to road or rail (and in some instances water). A logit model formulation is used to estimate the share of freight that would be assigned for each mode. Coefficients are developed for each commodity group. Those movements that had a rail access distance greater than 25 miles are assigned to the truck mode.

For the truck portion of the SAM model that was developed from Reebie data, the conversion from tons to number of vehicles was performed using vehicle load factors. These vehicle load factors are adjusted from a single value per commodity group to a set of values related to trip length. Load factors were also increased 15 to 20 percent to provide a better match with traffic count data. Empty truck movements were also reduced to 40 percent of their original values to calibrate the truck volumes with observed truck counts.

3.3.4 Assignment

The truck trips developed by the Reebie data in the SAM are preloaded as the initial step in traffic assignment. Minimum travel time paths are used when assigning truck movements to the road network. An all or nothing procedure is used as there are no other vehicles being assigned at this point. Roadway capacities are then adjusted to account for trucks, and these adjusted values are used to calculate congestion impacts on road speeds and route selection.

The commercial vehicle trips were added to the passenger model. Passenger trips were disaggregated into time periods and assigned to the network using a shortest time algorithm that accounted for potential congestion in the assignment.

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[1] TxDOT, Statewide Analysis Model Theory Documentation, 1999

[2] Federal Highway Administration, Trip Distribution Modeling, 2002.

3.3.5 Validation

Freight tonnage and vehicle flow estimates in the truck component of the SAM that are generated from the trip generation, distribution, and mode choice models are compared with the Reebie TRANSEARCH database from 1998 and traffic counts of commercial combination vehicles from 1998. Many comparisons were done on a geographic basis, for six districts within Texas, and four districts outside the State. Production and attraction totals by district determined the performance of the trip generation model, while flows between districts were used to determine the quality of the trip distribution model. Summaries of district-to-district tonnage by mode were used to evaluate the performance of the mode choice model. Truck vehicle trips produced by the mode choice model were assigned to the road network and comparisons between estimated and observed truck VMT, by area and by road type, were used as a final performance measure. The comparisons validated the model formulation for the truck component of the model that was developed from the Reebie model.

Because the commercial vehicle trips were included in the passenger model, there was no validation of commercial vehicle truck trips as a separate entity. Rather, the passenger model was validated using counts of passenger cars in the State's count program.

4.0 Alternative Estimates for Truck VMT

4.1 TRUCK VMT ESTIMATES USING HPMS DATA

TxDOT prepared a set of files that were extractions from their roadway inventory database. This is the same database from which Texas provides data for its HPMS submissions to the FHWA. The dataset contains information for all links on the State Highway Network as well as available county and local roads, with milepost markers for the start and end of each segment. A VMT calculation was provided for each particular segment. This calculation is made by taking the truck count for that segment and multiplying it by the segment distance. As an example, two consecutive truck counts of 10,000 and 14,000 separated by five miles would result in an estimated 60,000 VMT. This is calculated by taking the average of the two truck counts (12,000) and multiplying it by the distance of five miles.

Truck counts can be taken anywhere along the segment. There is no fixed midpoint or endpoint where counts are taken. Some segments in the file are subsections of a larger segment from which a count is taken. Therefore, the same number of trucks will be listed for consecutive segments in the file. Tables 4.1 and 4.2 show daily VMT calculations for all available segments in the nine-county Dallas metro area and the eight-county Houston area, respectively.

Table 4.1 Dallas Metropolitan Area Seasonally-Adjusted Daily VMT Estimates from HPMS Data, 2002

County	State Highway VMT	County Road and Local Road VMT	County VMT Total
Dallas	3,038,459	687,864	3,726,323
Tarrant	1,932,625	327,412	2,260,037
Denton	882,946	56,110	939,056
Ellis	812,659	6,094	818,752
Collin	617,876	116,457	734,333
Parker	515,496	8,916	524,412
Kaufman	474,826	4,278	479,104
Johnson	335,318	10,913	346,230
Rockwall	158,699	716	159,415
Total Dallas Area	8,768,903	1,218,760	9,987,663

Table 4.2 Houston Metropolitan Area Seasonally-Adjusted Daily VMT Estimates from HPMS Data, 2002

County	State Highway VMT	County Road and Local Road VMT	County VMT Total
Brazoria	433,118	34,184	467,302
Chambers	439,272	2,187	441,459
Fort Bend	553,798	56,654	610,452
Galveston	242,543	28,245	270,788
Harris	3,897,440	993,878	4,891,318
Liberty	265,179	6,157	271,336
Montgomery	732,922	60,176	793,098
Waller	305,666	4,215	309,881
Total Houston Area	6,869,938	1,185,696	8,055,634

4.2 TRUCK VMT ESTIMATES USING REEBIE DATA

As mentioned previously, data on commodity flow movements were obtained from TxDOT from the Reebie TRANSEARCH database for the base year 1998. WEFA forecasts for truck tons were also available for use for the years 2010 and 2025 for each commodity type (based upon STCC code) at the county level. Tables 4.3 and 4.4 show tonnage percentages for the base year of 1998, and the forecasts for 2010 and 2025 for the metropolitan areas of Dallas and Houston.

Table 4.3 Originating and Terminating Tons for Dallas Metropolitan Area

	Originating Tons			Terminating Tons		
County	**1998**	**2010**	**2025**	**1998**	2020	2025
Collin County	1%	1%	2%	1%	1%	2%
Dallas County	12%	14%	15%	17%	16%	16%
Denton County	0%	1%	1%	1%	1%	1%
Ellis County	1%	1%	1%	0%	1%	1%
Johnson County	0%	1%	1%	0%	0%	0%
Kaufman County	0%	0%	0%	0%	0%	0%
Parker County	0%	0%	0%	0%	0%	0%
Rockwall County	0%	0%	0%	0%	0%	0%
Tarrant County	5%	5%	6%	5%	5%	6%
Percent of Total Texas Tons in Dallas Metro Area	19%	23%	25%	25%	25%	26%

Percent of Total Texas Tons outside Dallas Metro Area	**81%**	**77%**	**75%**	**75%**	**75%**	**74%**

Table 4.4 Originating and Terminating Tons for Houston Metropolitan Area

	Originating Tons			**Terminating Tons**		
County	**1998**	**2010**	**2025**	**1998**	**2020**	**2025**
Brazoria County	2%	1%	1%	2%	2%	2%
Chambers County	0%	0%	0%	0%	0%	0%
Fort Bend County	1%	1%	1%	1%	1%	1%
Galveston County	2%	2%	1%	1%	1%	1%
Harris County	28%	26%	22%	27%	26%	25%
Liberty County	0%	0%	0%	0%	0%	0%
Montgomery County	0%	0%	0%	1%	1%	1%
Waller County	0%	0%	0%	0%	0%	0%
Percent of Total Texas Tons in Houston Metro Area	33%	30%	25%	32%	31%	30%
Percent of Total Texas Tons outside Houston Metro Area	67%	70%	75%	68%	69%	70%

The tables show that in 1998, 20 percent and 32 percent of tonnage in the State moved through the metropolitan areas of Dallas and Houston, respectively. The percentage is forecast to stay almost the same for the Houston Areas through 2025, while the percentage of tons that are forecast to move through Dallas are expected to increase slightly to greater than 20 percent in 2025.

The tons shown above were converted into truck trips on the basis of payload factors derived from the Vehicle Inventory and Use Survey (VIUS). The VIUS collects sample data at the metropolitan level for each state to produce statistics of average tons per truck by commodity type. The payload factors were further divided into two types: local and long-distance trips to account for variance in payload based upon trip length. Adjustments for empty truck trips are also included in the payload factors provided by VIUS. The final payload factors are shown in Table 4.5. The tonnage trip table and resulting truck trip table by trip type are shown in Tables 4.6 and 4.7, respectively.

Table 4.5 Payload Factors by STCC Code and Truck Trip Length (Tons per truck)

STCC Code	Name	Payload Factors	
		Local	Long
1	Farm Products	15.20	18.49
8	Forest Products	12.50	13.27
9	Fresh Fish or Marine Products	8.16	15.47
10	Metallic Ores	17.89	25.77
11	Coal	17.89	25.77
13	Crude Petroleum or Natural Gas	17.01	17.84
14	Nonmetallic Minerals	17.89	25.77
19	Ordnance or Accessories	5.74	10.87
20	Food or Kindred Products	8.16	15.47
21	Tobacco Products	13.87	14.49
22	Textile Mill Products	2.46	17.94
23	Apparel or Related Products	2.46	17.94
24	Lumber or Wood Products	11.34	17.65
25	Furniture or Fixtures	3.09	11.22
26	Pulp, Paper or Allied Products	5.87	15.14
27	Printed Matter	5.87	15.14
28	Chemicals or Allied Products	10.28	19.35
29	Petroleum or Coal Products	17.01	17.84
30	Rubber or Misc. Plastics	5.74	10.87
31	Leather or Leather Products	2.46	17.94
32	Clay, Concrete, Glass or Stone	12.58	18.66
33	Primary Metal Products	13.27	20.08
34	Fabricated Metal Products	7.67	14.49
35	Machinery	9.76	17.28
36	Electrical Equipment	5.73	14.68
37	Transportation Equipment	8.30	16.10
38	Instruments, Photo Equipment, Optical Equipment	9.76	17.28
39	Misc. Manufacturing Products	5.44	12.97
50	Drayage, Warehousing and Distribution	8.36	14.92
40	Misc. Freight	5.44	12.97
41	Misc. Freight	5.44	12.97
42	Misc. Freight	5.44	12.97
43	Misc. Freight	5.44	12.97
44	Misc. Freight	5.44	12.97
45	Misc. Freight	5.44	12.97
46	Misc. Freight	5.44	12.97
47	Misc. Freight	5.44	12.97

Table 4.6 Tonnage Estimate by Trip Type for Houston and Dallas Metropolitan Areas

	Tons (1998)	Tons (2010)	Annual Growth Rate (1998-2010)	Tons (2010)	Annual Growth Rate (2010-2020)
Houston Metropolitan Area					
I-I	38,708,272	51,217,821	2.36	72,217,821	3.50
I-X	128,263,545	161,257,884	1.93	214,053,921	2.87
X-I	121,820,367	171,673,576	2.90	282,031,044	5.09
X-X	44,166,081	82,040,366	5.30	115,774,114	3.50
Dallas Metropolitan Area					
I-I	27,242,659	44,941,905	4.26	79,199,685	5.83
I-X	80,593,307	123,858,121	3.65	206,919,433	5.27
X-I	104,642,980	143,857,390	2.69	223,769,981	4.52
X-X[a]	98,156,775	153,597,692	3.80	235,337,906	4.36

[a] Tonnage for Out-of-State to Out-of-State trips not available for 1998.

Table 4.7 Truck Trip Table Estimate by Trip Type for Houston and Dallas Metropolitan Areas

	Trucks (1998)	Trucks (2010)	Annual Growth Rate (1998-2010)	Trucks (2020)	Annual Growth Rate (2010-2020)
Houston Metropolitan Area					
I-I	3,189,427	4,390,519	2.70	6,446,146	3.92
I-X	7,223,616	9,173,878	2.01	12,466,707	3.11
X-I	7,255,521	10,232,403	2.91	16,919,419	5.16
X-X	3,768,052	4,881,016	2.18	6,992,473	3.66
Dallas Metropolitan Area					
I-I	2,213,099	3,592,988	4.12	6,205,290	5.62
I-X	4,691,692	7,178,530	3.61	12,019,204	5.29
X-I	6,146,210	8,465,638	2.70	13,317,376	4.63
X-X[a]	7,139,568	9,246,629	2.18	14,340,445	4.49

[a] Tonnage for Out-of-State to Out-of-State trips not available for 1998.

4.2.1 Developing VMT Estimates from Truck Trip Table

Distances between county pairs are then applied to the county-to-county truck flows to generate VMT estimates. To determine VMT incurred within the geographic boundaries of the metropolitan areas of Dallas and Houston, only the relevant distances between county pairs must be developed for the county-level trip table. The relevant distance for calculating metropolitan area VMT is the portion of the trip that occurs with the metropolitan area boundary. For example, between an internal county to an external county, the relevant distance would be from the internal county origin to the outer boundary of the metropolitan area closest to the external region. Likewise, from an external county to a metropolitan county, the distance calculated would be from the metropolitan boundary to the internal county. Since there are many origins (or destinations) within a county, distances are taken from the centroid of the county. A straight-line distance is not taken from the centroid to the metropolitan boundary, rather, a distance measurement is estimated by following a path that uses interstates or major state highways. The boundary at which flows enter or exit a metropolitan area depends on the trajectory of the origin-destination (O-D) pair as well as the available interstate or state highways route between the two zones.

While internal-external and external-internal flows incur VMT based on the distance from the metropolitan boundary to the centroid of an internal county, difference procedures are taken to calculate VMT for internal-internal and external-external movements. There are two types of internal-internal movements. One involves movements between counties within a metropolitan area. In this scenario, the centroid-to-centroid distances are taken. As for truck movements that originate and end within the same county, an average radius of the county was taken.

VMT from external-external flows depend on the geographic relationship between the origin and destination counties and the available major routes that connect them. Rather than determining paths for all O-D pairs in the network, the process is simplified by grouping the counties in the State into one of 16 regions. Reebie zones outside of the State are associated with one of the internal regions bounding the state line. Regions were delineated based on the trajectory of interstates or major state highways within the State. A map of the regions within Texas is shown in Figure 4.1. There is a preponderance of zones in the eastern half of the State as there are many trajectories that can be taken from each of the metropolitan areas of Dallas and Houston. From these relationships, it is possible to visually determine on a map, which zonal pairs will result in a trip that goes through Dallas and/or Houston. Table 4.8 describes each of the 16 zones and Table 4.9 matches each of the regional O-D combination to the metropolitan area(s) that they will pass-through.

Figure 4.1 Map of Regions within Texas

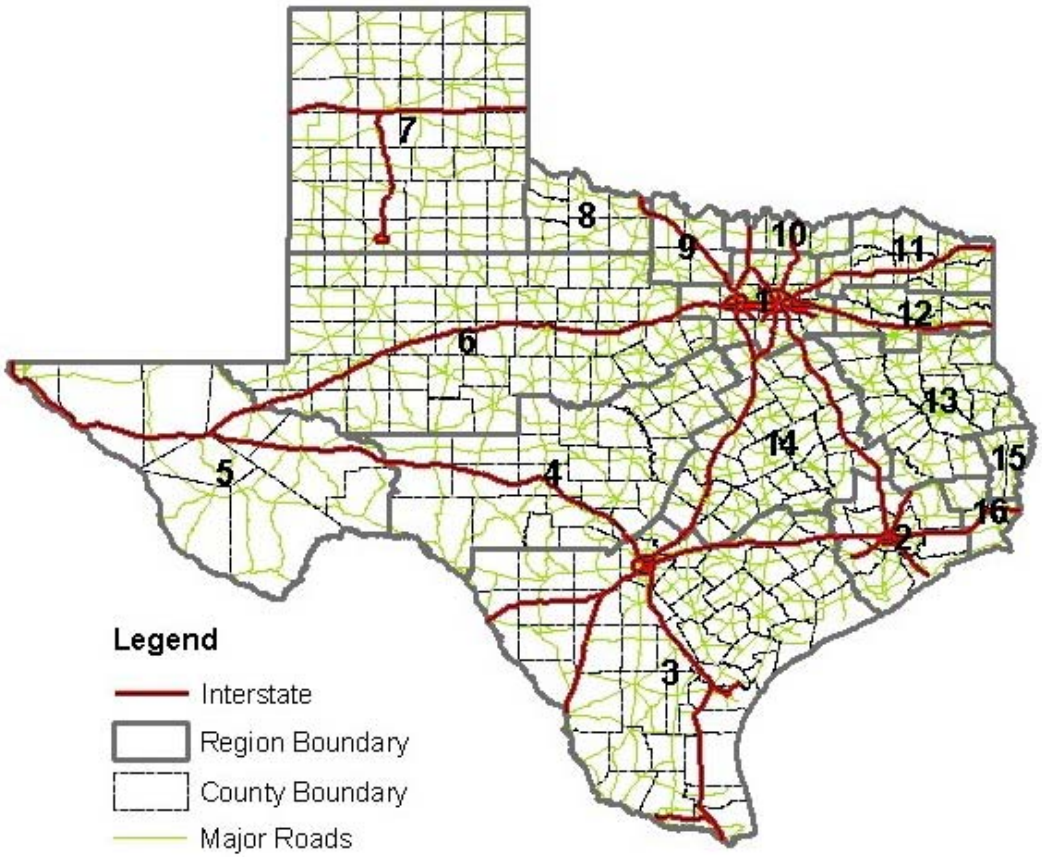

Table 4.8 Description of Zones

Zone	Description
1	Dallas metropolitan area
2	Houston metropolitan area
3	South Texas
4	San Angelo Region
5	Texas Panhandle
6	Abilene Region
7	Northwest Texas
8	Quanah Region
9	Wichita Falls Region
10	Sherman Region
11	Northeast Corner
12	Longview Region
13	Jacksonville Region
14	Waco Region
15	Jasper Region
16	Beaumont Region

Table 4.9 Matching Origin-Destination Combinations at the Zone Level to Metropolitan Areas

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1																HOU
2						DAL	DAL	DAL	DAL	DAL	DAL					
3									DAL	DAL	DAL		HOU		HOU	HOU
4										DAL	DAL	DAL				HOU
5										DAL	DAL	DAL	HOU		HOU	HOU
6		DAL								DAL	DAL	DAL	DAL	DAL	DAL	BOT
7		DAL										DAL	DAL	DAL	DAL	BOT
8		DAL										DAL	DAL	DAL	DAL	BOT
9		DAL	DAL									DAL	DAL	DAL	DAL	BOT
10		DAL	DAL	DAL	DAL	DAL								DAL	DAL	BOT
11		DAL	DAL	DAL	DAL	DAL								DAL		
12				DAL	DAL	DAL	DAL	DAL	DAL							
13			HOU		HOU	DAL	DAL	DAL	DAL							
14						DAL	DAL	DAL	DAL	DAL	DAL					HOU
15			HOU		HOU	DAL	DAL	DAL	DAL	DAL						
16	HOU		HOU	HOU	HOU	BOT	BOT	BOT	BOT	BOT				HOU		

Dallas = light shading; Houston = dark shading; Both = striped shading.

After determining which zone pairs result in a through trip, a distance is calculated for VMT incurred in a metropolitan area based on a path utilizing interstate or major state highways. The gateways from which trucks enter and exit a metro area depend on the trajectory of the two origin and destination zones. With distances calculated for all types of trips, internal-internal, internal-external, external-internal, and external-external, a VMT estimate is generated by multiplying the various distances accrued in the metro area for a given O-D pair by the number of trucks. Tables 4.10 and 4.11 show the VMT estimates for 1998, 2010 and 2025.

Table 4.10 Dallas Annual VMT Estimates from Reebie Data

Dallas	1998	2010	2025
Total VMT	**1,319,851,787**	**1,795,696,052**	**2,846,258,626**
Internal-External	237,079,446	360,123,522	601,936,702
External-Internal	309,170,859	425,313,427	669,556,897
Internal	38,056,070	62,421,535	111,237,410
Through	735,545,412	947,837,568	1,463,527,617

Table 4.1 Houston Annual VMT Estimates from Reebie Data

Houston	1998	2010	2025
Total VMT	**1,200,770,796**	**1,581,011,812**	**2,332,908,608**
Internal-External	387,973,781	485,623,576	651,580,115
External-Internal	386,988,350	541,834,089	886,116,528
Internal	55,907,394	75,702,179	113,982,341
Through	369,901,271	477,851,968	681,229,624

4.3 TRUCK VMT ESTIMATES USING SAM

The network geographic layer in the SAM is embedded with various properties, including VMT for each link. Therefore, total VMT can be calculated using the SAM output by summing the VMT for all links in SAM that are located within the metropolitan areas. New model runs were performed by the consultant team to generate VMT estimates from the SAM. These new model runs supersede previous model run outputs and provide the basis for VMT estimates using the SAM.

The standard SAM truck volume output only accounts for the truck trips generated by the Reebie data. These are assumed to be combination trucks, because the Reebie data are most accurate for long-haul truck trips. However, there are single-unit trucks that are estimated separately from the combination trucks. These single-unit trucks are generated as part of the passenger component of the SAM based on local socioeconomic data. For this project, the consultant team developed a separate set of calculations and model runs to account for the single-unit trucks that are currently subsumed into the passenger vehicle portion of the model. The single-unit trucks are potential candidates for TxLED consumption, while the four-tire commercial vehicles and passenger cars are assumed to be entirely powered by gasoline.

Trucks in the passenger model are tabulated utilizing the Quick Response Freight Manual trip generation rates. Three separate rates are used, a basic rate, a retail rate, and a service rate as shown in Table 4.12. Each rate is multiplied by the employment number for each category in each Traffic Analysis Zone (TAZ), thereby generating the number of single-unit truck productions for a TAZ.

Table 4.12 Trip Generation Rates for Single-Unit Trucks in SAM

Employment Type	Single-Unit Truck Trip Generation Rate (truck trips per employee)
Basic	0.123
Retail	0.068
Service	0.014

The trip distribution for the single-unit (SU) trucks was assumed to be the same as for the combined SU passenger car eall of the commercial vehicles. Therefore, the trip distribution for the single-unit trucks was developed by proportionally assigning the trip ends from the commercial vehicle model to the single-unit truck model. The single-unit trucks were then assigned in the model as a separate vehicle class so that the model volumes would be a distinct output of each model run. Then, using the same procedure described in Section 2.0, the VMT was calculated for each of the relevant trip types for the single-unit trucks.

The truck trip table for single-unit trucks is then combined with the truck trip for combination trucks (generated from the Reebie data) in preparation for running

the model. However, prior to assignment, it is necessary to identify the O-D combinations that will result in trips passing through Dallas and/or Houston, and thereby accumulate VMT in a metropolitan region.

As with the process described in Section 4.2, each county is assigned to one of 16 zones that make up the State of Texas. TAZs and counties located outside of the State were associated with one of the internal regions bounding the state line. The VMT estimates in Section 4.2 require calculating distances manually. However, when running the SAM, the shortest path is calculated automatically using the model. A dummy variable is assigned for each TAZ-level, O-D pair to determine if the trip is an internal-internal, external-external, internal-external, or external-internal trip for a given metropolitan area.

With the dummy variables in place, the SAM is run and the resultant output is a listing of all the roadway links in the SAM network with daily VMT incurred on the link by all truck trips. The data are also disaggregated into VMT by combination trucks and single-unit trucks. To determine the VMT for a metropolitan area, a summation is taken of all link VMT located within Dallas, and another calculation is made for Houston. Tables 4.13 and 4.14 show the VMT by trip type and truck type for 1998 and 2025 for Dallas and Houston using the SAM.

Table 4.93 Dallas SAM VMT Estimates, 1998 and 2025

Dallas		Total VMT	Combination Truck VMT	Single-Unit Truck VMT
	1998	1,624,653,690	1,122,042,120	502,611,570
	2025	3,321,777,400	2,560,735,975	761,041,425
Internal-External				
	1998	275,423,160	272,382,345	3,040,815
	2025	619,460,480	615,230,130	4,230,350
External-Internal				
	1998	316,178,695	305,427,985	10,750,710
	2025	744,749,285	729,673,690	15,075,595
Internal				
	1998	568,022,490	79,280,920	488,741,570
	2025	942,762,880	201,138,725	741,624,155
Through				
	1998	465,029,345	464,950,870	78,475
	2025	1,014,804,755	1,014,693,430	111,325

Table 4.104 Houston SAM VMT Estimates, 1998 and 2025

Houston		Total VMT	Combination Truck VMT	Single-Unit Truck VMT
	1998	1,656,425,480	1,230,738,025	425,687,455
	2025	3,148,651,330	2,551,873,410	596,777,920
Internal-External				
	1998	526,841,000	525,406,915	1,434,085
	2025	953,460,665	951,423,235	2,037,430
External-Internal				
	1998	457,026,720	452,837,980	4,188,740
	2025	1,014,467,130	1,008,713,270	5,753,860
Internal				
	1998	504,482,925	84,508,085	419,974,840
	2025	755,844,190	166,984,945	588,859,245
Through				
	1998	168,074,835	167,985,045	89,790
	2025	424,879,710	424,752,325	127,385

4.4 TRUCK VMT ESTIMATES USING METROPOLITAN-LEVEL MODELS

Another source for truck VMT estimates are the MPO travel demand models for Dallas and Houston. The NCTCOG model creates separate outputs for trucks and passenger cars. The truck output is used to create the annual truck VMT estimate for the region as shown in Table 4.15. The H-GAC travel demand model vehicle output does not include information on vehicle classification. To estimate truck activity from this model vehicle classification factors are applied as a post-processor. Table 4.16 shows the VMT for heavy-duty diesel vehicles by county for the Houston/Galveston/Brazoria area.

Table 4.115 VMT Estimates by Type of Vehicle for the Dallas Metropolitan Area, 1999

County	Light Duty Vehicles	Heavy-Duty Gasoline Trucks	Heavy-Duty Diesel Trucks	Buses	Total
Dallas	59,886,079	1,058,959	3,400,368	132,164	64,477,570
Tarrant	36,779,866	641,164	2,112,016	75,188	39,608,233
Collin	11,042,885	108,780	650,360	7,415	11,809,440
Denton	10,682,447	113,617	683,441	7,696	11,487,202
Total	118,391,277	1,922,520	6,846,185	222,463	127,382,445

Source: North Central Texas Council of Governments.

Table 4.126 VMT Estimate for HDDVs for Houston/Galveston/Brazoria Area, 1999

County	VMT
Harris	4,787,220
Brazoria	282,918
Fort Bend	174,074
Waller	89,514
Montgomery	191,527
Liberty	104,718
Chambers	112,869
Galveston	313,034
Total	6,055,872

4.5 CONCLUSIONS ON TOTAL VMT

This section has described several different sources of VMT estimates for trip types in the Houston and Dallas metropolitan areas. In the next section, these estimated will be integrated to develop a single set of VMT estimates that is most relevant for understanding the consumption of TxLED fuel.

5.0 Development of VMT Estimates

Section 5.0 integrates the VMT estimates described in the previous section into a single set of VMT estimates by trip type for each metropolitan area. This section also describes the methodology used to develop forecasts of the VMT estimates. Next, a process is described to extract the diesel truck VMT from the total VMT estimate. Finally, a roadside truck intercept survey is used to estimate the percentage of diesel truck VMT that is likely to be fueled in Texas and therefore likely candidates t be fueled using TxLED.

Table 5.1 shows various VMT estimates for Dallas. The estimates of total VMT range from 6.8 million miles from the MPO travel demand model to 10.0 million miles using the HPMS vehicle classification data. Table 5.2 shows a range of total VMT estimates for Houston between 4.5 million using the SAM and 8.1 million using the HPMS data.

Table 5.1 Dallas Base-Year VMT Estimates

	VMT Estimation Type					
Trip Type	HPMS (Weekday, 2002)	SAM Combination Units (Daily)	SAM – Single Units (Daily)	SAM – Total (Daily)	Reebie Data Only (Annual)	MPO Model (Daily)
Total	9,987,663	3,074,088	1,377,018	4,451,106	1,319,851,787	6,846,185
Through	N/A	1,273,838	215	1,274,053	735,545,412	N/A
I-X	N/A	746,253	8,331	754,584	237,079,446	N/A
X-I	N/A	836,789	29,454	866,243	309,170,859	N/A
Internal	N/A	217,208	1,339,018	1,556,226	38,056,070	N/A

Table 5.2 Houston Base-Year VMT Estimates

	VMT Estimation Type					
Trip Type	HPMS (Weekday, 2002)	SAM Combination Units (Daily)	SAM – Single Units (daily)	SAM – Total (Daily)	Reebie Data Only (Annual)	MPO Model (Daily)
Total	8,055,634	3,371,885	1,166,267	4,538,152	1,200,770,796	6,673,985
Through	N/A	460,233	246	460,479	369,901,271	N/A
I-X	N/A	1,439,471	3,929	1,443,400	387,973,781	N/A
X-I	N/A	1,240,652	11,476	1,252,128	386,988,350	N/A
Internal	N/A	231,529	1,150,616	1,382,145	55,907,394	N/A

5.1 INTEGRATION OF VMT ESTIMATES

The accuracy of a VMT estimate depends on a multitude of factors including the breadth of coverage of the source data for the estimate, the accuracy of the data that are used, and the degree to which the data are collected from local sources. The TxDOT vehicle classification data (HPMS data) rate well for each of these characteristics. The HPMS data cover each of the roadway functional classes. The data are spread throughout all portions of the Dallas and Houston metropolitan areas. Also, the HPMS data are relatively easy to collect and are therefore they are likely relatively accurate. Therefore, the VMT estimates derived from the TxDOT vehicle classification data are likely to be the most accurate and are recommended for the final VMT estimation.

While the truck VMT estimates developed from the travel demand models satisfy the needs and purposes of the models, none of the other data sources have the same characteristics as the HPMS data in terms of accuracy. In the SAM and the NCTCOG travel demand models, the truck trip generation rates are based on data collected in a metropolitan region outside of Texas. The HGAC travel demand model generated truck VMT estimates only as a post-processor to the standard model output. The HGAC model does not reflect truck activity as a separate entity in trip generation or trip distribution.

The HPMS data are based on actual truck activity. However, the HPMS data do not provide any information on trip types (e.g., internal, through, internal-external), because they do not incorporate any kind of O-D information. The best source data for intercity O-D information is the Reebie TRANSEARCH data. These data were used to develop the truck trip table of the SAM model and to develop the Reebie estimates shown in Tables 5.1 and 5.2. However, because the SAM outputs are based on assigning flows to the network based on shortest path rather than the more subjective methods incorporated into the Reebie analysis, the SAM model is the preferred method for developing estimates of the VMT for each of the through trip types. Therefore, the final estimate of VMT was developed by proportioning the trip type VMT estimates from the SAM to the VMT totals developed through the HPMS data. The 1998 VMT estimates for each of the trip types for the Dallas and Houston metropolitan area are shown in Table 5.3.

The VMT estimates developed from this process are disaggregated into combination and single-unit trucks as shown in Table 5.4. This disaggregation will be used in the development of forecasts and fuel consumption rates in each metropolitan area.

Table 5.3 Final VMT Estimates by Trip Type (1998)

Trip Type	Dallas Metro Area	Percent of Total	Houston Metro Area	Percent of Total
Total	9,987,663	100%	8,055,634	100%
Through	2,858,798	29%	817,392	10%
I-X	1,693,182	17%	2,562,167	32%
X-I	1,943,729	19%	2,222,641	28%
Internal	3,491,955	35%	2,453,434	30%

Table 5.4 Disaggregated Final VMT Estimates by Trip Type (1998)

Trip Type	Dallas Metro Area	Dallas – Comb Trucks	Dallas – SU Trucks	Houston Metro Area	Houston – Comb Trucks	Houston – SU Trucks
Total	9,987,663	6,897,826	3,089,837	8,055,634	5,985,404	2,070,230
Through	2,858,798	2,858,315	482	817,392	816,956	437
I-X	1,693,182	1,674,488	18,694	2,562,167	2,555,192	6,974
X-I	1,943,729	1,877,638	66,091	2,222,641	2,202,271	20,371
Internal	3,491,955	487,385	3,004,570	2,453,434	410,985	2,042,448

5.2 FORECASTS OF VMT ESTIMATES

The years of concern for emissions analysis performed at the TCEQ are 2002, 2007, 2010, and 2020. Therefore, the 1998 base-year data must be forecast to account for each of these future years. There are several sources that can be used to forecast truck VMT. TTI develops estimates of truck VMT based on historical trends in truck VMT. Forecasts are also available in travel models of the Houston and Dallas metropolitan areas. These forecasts are driven by changes in employment and households in the socioeconomic data that underlie the model. However, as mentioned in Section 3.0, the forecast of freight flows in the SAM are driven in part by forecasts of future economic conditions. Freight flow forecasts built on economic forecasts are more accurate than forecasts built on employment data, because productivity improvements will increase the amount of goods produced per employee in the future relative to today. Forecasts based solely on employment data will underestimate the amount of goods that are produced. Therefore, the forecasts of VMT used in this analysis are performed using the forecasts in the SAM. Tables 5.5 and 5.6 show the calculation of annual growth rates for Dallas for combination and single-unit trucks respectively. Tables 5.7 and 5.8 show similar calculations for the Houston metropolitan area. Note that the VMT values in the first two columns of Tables 5.5 to 5.8 are the output of the SAM and not the final VMT estimates that are recommended as part of this study and shown in Tables 5.3 and 5.4.

Table 5.5 Dallas 2020 Calculation of Growth Rates for Combination Trucks

Trip Type	SAM Comb Trucks (1998)	SAM Comb Trucks (2025)	Annual Growth Rates
Total	3,074,088	7,015,715	3.10%
Through	1,273,838	2,779,982	2.93%
I-X	746,253	1,685,562	3.06%
X-I	836,789	1,999,106	3.28%
Internal	217,208	551,065	3.51%

Table 5.6 Dallas 2020 Calculation of Growth Rates for Single-Unit Trucks

Trip Type	SAM Single-Unit Trucks (1998)	SAM Single-Unit Trucks (2025)	Annual Growth Rates
Total	1,377,018	2,085,045	1.55%
Through	215	305	1.30%
I-X	8,331	11,590	1.23%
X-I	29,454	41,303	1.26%
Internal	1,339,018	2,031,847	1.56%

Table 5.7 Houston 2020 Calculation of Growth Rates for Combination Trucks

Trip Type	SAM Comb Trucks (1998)	SAM Comb Trucks (2025)	Annual Growth Rate
Total	3,371,885	6,991,435	2.74%
Through	460,233	1,163,705	3.50%
I-X	1,439,471	2,606,639	2.22%
X-I	1,240,652	2,763,598	3.01%
Internal	231,529	457,493	2.55%

Table 5.8 Houston 2025 Calculation of Growth Rates for Single-Unit Trucks (VMT)

Trip Type	SAM Single-Unit Trucks (1998)	SAM Single-Unit (2025)	Annual Growth Rate
Total	1,166,267	1,635,008	1.26%
Through	246	349	1.30%
I-X	3,929	5,582	1.31%
X-I	11,476	15,764	1.18%
Internal	1,150,616	1,613,313	1.26%

The growth rates shown in Tables 5.5 through 5.8 are applied to the base-year rates shown in Table 5.4 to develop the final VMT forecasts for 2025. The combined VMT forecasts for the Dallas and Houston metropolitan areas are shown in Table 5.9. The disaggregated VMT forecasts are shown in Table 5.10. Note that the growth rates for the internal trips are roughly half the amount of the growth rates for the other trip types. The lower growth rates for internal trips occur because the methodology for forecasting internal trips in the SAM are tied to employment growth. The growth rates for the internal-external, external-internal and through trips are based on freight flow estimates derived from economic output forecasts that account for productivity improvements. The lower growth rates of the internal trips result in their percentage of total VMT decreasing in the forecast years relative to the other trip types.

Table 5.9 Final Forecast VMT Estimates by Trip Type (2025)

Trip Type	Dallas Metro Area	Percent of Total	Houston Metro Area	Percent of Total
Total	20,420,005	100%	15,309,193	100%
Through	6,234,348	31%	2,068,797	14%
I-X	3,804,472	19%	4,632,574	30%
X-I	4,580,647	22%	4,932,681	32%
Internal	5,800,538	28%	3,675,141	24%

Table 5.10 Disaggregated Final VMT Forecasts by Trip Type (2025)

Trip Type	Dallas – Rb Fore	Dallas – QR Fore	Dallas – Total	Houston – Rb Fore	Houston – QR Fore	Houston – Total
Total	15,737,173	4,682,832	20,420,005	12,406,688	2,902,505	15,309,193
Through	6,233,664	684	6,234,348	2,068,178	619	2,068,797
I-X	3,778,468	26,004	3,804,472	4,622,663	9,911	4,632,574
X-I	4,487,972	92,675	4,580,647	4,904,719	27,962	4,932,681
Internal	1,237,069	4,563,468	5,800,538	811,127	2,864,013	3,675,141

The annual growth rates were also applied to the base-year data in order to develop VMT estimates for the target years for TCEQ: 2002, 2007, 2010, and 2020. These are shown in Tables 5.11 and 5.12.

Table 5.11 Dallas VMT Forecasts in TCEQ Model Years

Trip Type	Dallas Metro Area 2002 – Comb	Dallas Metro Area 2002 – SU	Dallas Metro 2002 – Total	Dallas Metro Area 2007 – Comb	Dallas Metro Area 2007 – SU	Dallas Metro 2007 – Total
Total	7,793,242	3,286,112	11,079,354	9,078,332	3,549,100	12,627,432
Through	3,208,323	508	3,208,831	3,706,704	542	3,707,246
I-X	1,889,046	19,630	1,908,677	2,196,308	20,868	2,217,176
X-I	2,136,372	69,485	2,205,857	2,510,487	73,974	2,584,461
Internal	559,501	3,196,488	3,755,990	664,833	3,453,716	4,118,549

Trip Type	Dallas Metro Area 2010 – Comb	Dallas Metro Area 2010 – SU	Dallas Metro 2010 – Total	Dallas Metro Area 2020 – Comb	Dallas Metro Area 2020 – SU	Dallas Metro 2020 – Total
Total	9,949,361	3,716,901	13,666,262	13,505,632	4,335,743	17,841,375
Through	4,042,163	563	4,042,726	5,395,523	641	5,396,164
I-X	2,404,162	21,647	2,425,809	3,249,863	24,462	3,274,325
X-I	2,765,710	76,806	2,842,516	3,819,170	87,051	3,906,221
Internal	737,326	3,617,884	4,355,210	1,041,076	4,223,588	5,264,665

Table 5.12 Houston VMT Forecasts in TCEQ Model Years

Trip Type	Houston Metro Area 2002 – Comb	Houston Metro Area 2002 – SU	Houston Metro 2002 – Total	Houston Metro Area 2007 – Comb	Houston Metro Area 2007 – SU	Houston Metro 2007 – Total
Total	6,661,411	2,176,506	8,837,917	7,618,407	2,317,056	9,935,463
Through	937,475	460	937,935	1,113,427	491	1,113,917
I-X	2,789,762	7,347	2,797,109	3,113,483	7,841	3,121,324
X-I	2,479,638	21,350	2,500,987	2,875,975	22,639	2,898,615
Internal	454,536	2,147,350	2,601,886	515,522	2,286,085	2,801,607

Trip Type	Houston Metro Area 2010 – Comb	Houston Metro Area 2010 – SU	Houston Metro 2010 – Total	Houston Metro Area 2020 – Comb	Houston Metro Area 2020 – SU	Houston Metro 2020 – Total
Total	8,259,499	2,405,706	10,665,205	10,827,350	2,726,441	13,553,791
Through	1,234,476	510	1,234,986	1,741,350	580	1,741,930
I-X	3,325,478	8,153	3,333,632	4,142,027	9,287	4,151,313
X-I	3,143,571	23,450	3,167,022	4,228,800	26,369	4,255,169
Internal	555,973	2,373,593	2,929,566	715,172	2,690,205	3,405,378

5.3 DISAGGREGATING VMT INTO TRUCK FUEL TYPES

The SAM develops two types of truck trips: 1) truck trips developed from the Reebie TRANSEARCH data and 2) truck trips developed from the Quick Response Freight Manual (QRFM). The SAM considers the trucks developed from the Reebie data to be combination trucks and the trucks developed by the QRFM to be single-unit trucks. The truck trips developed by the Reebie data were validated by truck VMT and some count data of combination trucks developed by TxDOT. Therefore, the SAM assumptions can be considered reasonable.

The division of truck trips into combination and single-unit trucks enable estimates to be created for the disaggregation of truck VMT into fuel classes. Table 5.13 shows the percentages of VMT driven by trucks of different fuel types. These percentages were generated from the Vehicle Inventory and Use Survey (VIUS) for the State of Texas. The VIUS is a survey-based dataset with information on vehicle characteristics and trip types for each state. Table 5.13 is based on cross-tabs of three characteristics from the VIUS data: truck type, fuel type, and VMT. It shows that all of the VMT of the combination trucks will be attributable to diesel engines. However, gasoline-powered engines are present in roughly 40 percent of the VMT for single-unit trucks. These percentages will be used in the next set of estimates on the "capture rate" of the TxLED program.

Table 5.13 Distribution of Truck VMT by Truck Type and Fuel Type

Truck Type	Diesel	Other Fuel	Total
Single-Unit (%)	59%	41%	100%
Combination (%)	100%	0%	100%

5.4 ESTIMATING FUEL CONSUMPTION FROM A LOCAL TRUCK TRAVEL SURVEY

The final step in estimating the consumption of diesel fuel sold in the region is to correlate fuel consumption with truck trip types. There was no preexisting comprehensive dataset that provides this correlation. Therefore, a truck travel survey was conducted specifically for this project at a Texas State Highway Patrol weigh station 35 miles east of the Houston metropolitan area on Interstate 35. This survey asked truck drivers for ultimate O-D information, last/next fuel stop information, and commodity type. These data were used to estimate the percentage of diesel truck VMT that is purchased regionally as shown in Table 5.14. These percentages are applied to the truck VMT as shown in Tables 5.15 and 5.16 to estimate the actual truck VMT that is likely to be fueled by regional fuel. This calculation assumes that TxLED fuel will be available in all counties in the state. Chapter 7 discusses a methodology that can be employed to estimate the fuel usage if TxLED is available only in certain counties or is phased-in slowly.

Table 5.14 Correlation of Truck Trip Types to Percent using TxLED Program

Trip Type ID	Truck Trip Type	Percent of Trucks with Last Fuel Purchase inside Texas
1	Internal Trips	71%
2	I-X Trips with external trip end in Texas	86%
3	I-X Trips with external trip end outside Texas	38%
4	X-I Trips with external trip end in Texas	93%
5	X-I Trips with external trip end outside Texas	32%
6	X-X Trips with no trip ends in Texas	41%
7	X-X Trips with destination only in Texas	30%
8	X-X Trips with origin only in Texas	90%
9	X-X Trip ends with both trip ends in Texas	82%

Table 5.15 Dallas Metro Area Truck VMT Estimates by Disaggregated Trip Type

Trip Type ID	Diesel Truck VMT	Percent Estimate VMT That Is Fueled by TxLED	Truck VMT Using TxLED
1	2,445,429	71%	1,736,255
2	1,425,471	86%	1,225,905
3	475,157	38%	180,560
4	1,524,158	93%	1,417,467
5	653,210	32%	209,027
6	609,638	41%	249,952
7	609,638	30%	182,891
8	673,811	90%	606,430
9	1,283,449	82%	1,052,428

Note: SU Nondiesel VMT have been removed from this table.

Table 5.16 Houston Metro Area Truck VMT Estimates by Disaggregated Trip Type

Trip Type ID	Diesel Truck VMT	Percent Estimate VMT That Is Fueled by TxLED	Truck VMT Using TxLED
1	1,721,473	71%	1,222,246
2	1,648,517	86%	1,417,725
3	1,145,580	38%	435,320
4	1,545,185	93%	1,437,022
5	947,049	32%	303,056
6	290,701	41%	119,187
7	121,907	30%	36,572
8	187,549	90%	168,794
9	337,589	82%	276,823

Note: SU Nondiesel VMT have been removed from this table.

5.5 SUMMARY OF TXLED USAGE RATES

Tables 5.17 and 5.18 show the VMT estimates for total trucks, diesel trucks and TxLED fuel for both metropolitan areas. The trip types with the highest percentage of TxLED usage are internal-external and external-internal trips. It is estimated that between 66 percent and 74 percent of the VMT of these trip types would use TxLED fuel. The high percentage of TxLED fuel usage for these trips is the result of both a high percentage of diesel fuel usage and high probabilities of refueling in the State of Texas. The percentage of TxLED usage is slightly higher for the Dallas metropolitan area, because the percentage of I-X/X-I trips for that are fueled within the State are higher for Dallas than for Houston. The percentage of through trips for the metropolitan areas that are estimated to use TxLED fuel are 65 percent and 64 percent for Dallas and Houston respectively. Although nearly all of these truck trips are by diesel trucks, the slightly lower percentages are attributable to the lower percentages of trucks that are fueled within the State. The lowest TxLED fuel usage is for truck trips for internal truck trips. These low percentages are primarily due to the fraction of internal trucks that use gasoline rather than diesel. However, there are also a percentage of internal truck trips that report their last fueling outside of Texas. This could happen for trucks that are based and fueled in Louisiana, but make multiple stops in the Houston metropolitan region. If the truck survey captured this type of truck in between two Houston stops, then they would have been reported as internal truck trips with their last fueling outside of the State.

Table 5.17 Summary of TxLED Usage Rates for the Dallas Area (2002)

Trip Type	Dallas Metro Truck VMT	Dallas Metro Diesel VMT	VMT with TxLED Fuel
Total	11,079,354	9,732,048	6,860,915
Through	3,208,831	3,208,623	2,091,701
I-X	1,908,677	1,900,628	1,406,465
X-I	2,205,857	2,177,368	1,626,494
Internal	3,755,990	2,445,429	1,736,255

Table 5.18 Summary of TxLED Usage Rates for the Houston Area (2002)

Trip Type	Houston Metro Truck VMT	Houston Metro Diesel VMT	VMT with TxLED Fuel
Total	8,837,917	7,945,550	5,416,745
Through	937,935	937,746	601,377
I-X	2,797,109	2,794,097	1,853,045
X-I	2,500,987	2,492,235	1,740,078
Internal	2,601,886	1,721,473	1,222,246

6.0 Temporal Variability in Truck Activity

A portion of the TxDOT Roadway Inventory data were used to develop time-of-day factors for the Dallas and Houston metropolitan areas. These factors along with VMT during each hour are shown in Tables 6.1 and 6.2. To convert daily trips to annual trips, it is recommended that a factor of 313 is used. This factor was developed as part of a truck count study for the Southern California Association of Governments. The development of annual factors specific to the State of Texas was restricted by the time and budget constraints of this project.

Table 6.1 Time-of-Day Factors for Dallas Metropolitan Area

Hour	TOD Factor	2002 Hourly VMT
12:00 a.m.	0.2282	145,663
1:00 a.m.	0.1579	100,790
2:00 a.m.	0.1464	93,449
3:00 a.m.	0.1561	99,641
4:00 a.m.	0.2212	141,195
5:00 a.m.	0.4970	317,242
6:00 a.m.	0.9438	602,441
7:00 a.m.	1.0582	675,464
8:00 a.m.	1.0062	642,272
9:00 a.m.	0.9684	618,144
10:00 a.m.	0.9709	619,740
11:00 a.m.	0.9860	629,378
12:00 p.m.	1.0000	638,315
1:00 p.m.	1.0413	664,677
2:00 p.m.	1.0790	688,741
3:00 p.m.	1.1602	740,573
4:00 p.m.	1.1934	761,765
5:00 p.m.	1.1603	740,636
6:00 p.m.	0.9592	612,271
7:00 p.m.	0.6926	442,097
8:00 p.m.	0.5416	345,711
9:00 p.m.	0.5092	325,030
10:00 p.m.	0.3961	252,836
11:00 p.m.	0.2840	181,281

Table 6.2 Time-of-Day Factors for Houston Metropolitan Area

Hour	Factor	2002 Hourly VMT
12:00 a.m.	0.140	72,685
1:00 a.m.	0.101	52,437
2:00 a.m.	0.101	52,437
3:00 a.m.	0.105	54,513
4:00 a.m.	0.188	97,605
5:00 a.m.	0.551	286,065
6:00 a.m.	1.125	584,072
7:00 a.m.	1.106	574,208
8:00 a.m.	1.058	549,287
9:00 a.m.	1.014	526,444
10:00 a.m.	1.011	524,886
11:00 a.m.	1.036	537,865
12:00 p.m.	1.000	519,175
1:00 p.m.	1.008	523,328
2:00 p.m.	1.037	538,385
3:00 p.m.	1.129	586,149
4:00 p.m.	1.159	601,724
5:00 p.m.	1.182	613,665
6:00 p.m.	0.943	489,582
7:00 p.m.	0.679	352,520
8:00 p.m.	0.455	236,225
9:00 p.m.	0.394	204,555
10:00 p.m.	0.294	152,637
11:00 p.m.	0.207	107,469

7.0 Conclusions on VMT Estimation Process and Estimates

This study has developed VMT estimates for several truck trip types and fuel usage types in the Dallas and Houston metropolitan areas. The methodology employed for this study can be implemented for other metropolitan areas as well. Therefore, the methodology could be used to estimate the potential effectiveness of implementing TxLED fuel anywhere in the State.

The methodology used in this project could be extended to calculate the amount of TxLED usage for scenarios in which TxLED was not available throughout the state. For these instances, a separate usage rate would be developed for each truck trip origin-destination combination. These usage rates would be based on data from the roadside survey. Then the VMT for each origin-destination combination would be calculated based on the SAM. With roughly 250 counties in the state and several external regions, the number of origin-destination combinations would have been over 62,000. The resources were not available as part of this study to create such a detailed usage estimation matrix. However, now that the methodology is proven and TxLED usage estimates for the entire state have been developed, it would require only a fraction of the resources used for this project to estimate TxLED usage for different TxLED roll-out scenarios.

7.1 Potential Implementation of the TxLED Program

The actual fuel use for diesel truck trips within Texas will depend on the counties in which TxLED fuel is available. The VMT estimates above are based on TxLED fuel being the sole diesel fuel throughout the State. Because, truck trip generation and attraction are concentrated in particular areas in the State, there are counties, which will be more important than others in terms of optimizing the usage of TxLED fuel relative to the counties where the fuel is available. Table 7.1 shows the combined truck tons generated and attracted to each of the counties in the State. This can be used as a proxy for locations with high diesel fuel consumption. Note that just 15 of the 254 counties in the State are responsible for over 70 percent of the truck trip generation and attraction. Five of these 15 counties are actually located in the Houston or Dallas metropolitan areas. The importance of these 15 counties could be corroborated by diesel fuel tax receipts from each of the counties in the State. (Diesel fuel consumption data were not available for this VMT study.)

Table 7.1 Total Truck Tons Originated and Destined to Top Counties in State

County	Total	Percent of Tons
Harris	276,467,468	25.5%
Dallas	154,757,081	14.3%
Bexar	70,943,423	6.5%
Tarrant	54,818,223	5.1%
Jefferson	31,823,487	2.9%
El Paso	30,174,954	2.8%
Travis	23,706,585	2.2%
Nueces	22,007,273	2.0%
Brazoria	19,135,067	1.8%
Galveston	15,176,192	1.4%
Hidalgo	14,947,449	1.4%
Potter	14,607,059	1.3%
Webb	14,509,261	1.3%
McLennan	14,075,499	1.3%
Cameron	10,721,444	1.0%
Other 239 Counties	316,515,796	29.2%
Total	1,084,386,261	100.0%

7.2 RECOMMENDED FUTURE DATA COLLECTION AND ANALYSIS TO IMPROVE ESTIMATES

The estimates of this project were developed from integrating several different data sources. This section recommends four areas for supplemental data collection and/or analysis that could be used to improve these estimates:

1. As mentioned in Section 3.1, the annual growth rates for truck trips internal to the metropolitan areas are tied to forecasts of employment growth. Using employment growth rates does not account for the impact of labor productivity. Labor productivity improvements results in an increased amount of goods.
2. Additionally, the estimate of TxLED fuel usage was generated off of a single survey in the Houston metropolitan area. A similar survey in the Dallas metropolitan area may yield some different results which would alter the estimate of TxLED fuel usage. In particular, the internal truck trips in the truck travel survey were reported to have 29 percent of the truck trips fueled outside of the State. However, this survey was taken east of Houston rela-

tively close to the Texas-Louisiana border. Therefore, a similar survey on the west side of Houston or in the Dallas metropolitan area may yield different results, particularly in regards to the percent of internal truck trips that are fueled within the State.

3. There is a significant amount of data that were not used in the development of the temporal factors for the metropolitan areas. Ideally, the entire TxDOT Road Inventory database would be used to develop time-of-day and day-of-week factors. However, these data were not available to the consultant team in time for this study.

4. The estimate of TxLED usage assumed that all fueling in the State of Texas will be with TxLED fuel. The actual TxLED program is scheduled to be phased in over time starting with certain counties first and then preceding to other important counties in the State. As shown in Table 7.1, TxLED fuel availability in just 15 of the 255 counties in the State will likely result in over 70 percent coverage of fuel usage in the State. However, to accurately reflect the phasing in of the TxLED program, the O-D information in the SAM could be used to determine the percentage of fuel activity that occurs in TxLED counties as opposed to non-TxLED counties.