Draft Report

Quantification of Selected Sources for Emission Inventory Improvement in El Paso, Texas

PREPARED FOR:

El Paso Metropolitan Planning Organization
El Paso, TX 79913

PREPARED BY:

Huiyan Yang[1]
Kelvin Ruey Long Cheu[2]
Teresa S. Montoya[2]
Rosa Fitzgerald[1]
Wen-Whai Li[2]

[1]Physics Department
[2]Department of Civil Engineering

The University of Texas at El Paso
El Paso, Texas 79968

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Table of Contents

List of Tables

List of Figures

Abstract

This report provides emission estimates for five sources previously identified in the Emission Inventory Improvement Plan (Li et al 2011). Emission estimates are provided in the respective sections in the report.

Light duty and heavy duty vehicles at the El Paso-Juarez international ports of entry (POEs) were found to emit a significant amount of pollutants while waiting to cross the border. NOx emissions at the POEs were found to be significant, adding ~5.5% of the total onroad NOx emissions in El Paso to the atmosphere. VOC emissions at the POEs were also found to be significant, releasing another ~2.0 % of the total onroad VOC emissions in El Paso to the atmosphere. Emissions from the El Paso International Airport (ELP) were also found to be significant for NOx, equivalent to ~4.5% of the total onroad NOx emissions in El Paso. VOC emissions from ELP were modest, at ~0.9% of the total onroad VOC emissions in El Paso. The locomotive emissions inventory was obtained from Union Pacific (UP) and Burlington-Northern Santa-Fe (BNSF). It was found that NOx emissions from locomotive could add ~40% of total nonroad NOx emissions or 5% of the total onroad NOx emissions in El Paso. The emission inventory for tactical operations at Ft. Bliss Military Reservation was provided by Ft. Bliss. NOx and VOCs emissions were judged insignificant compared to emissions from other sources although there are concerns about whether the emissions reflected accurately the emissions at the facilities and the locations/spatial distribution of these emissions. Emissions from the regional truck stops were concluded to be insignificant.

These emission estimates were not accounted for in the archived TCEQ emission inventories for the region. Inclusion of these emissions in the region's photochemical air quality modeling study will help improve understanding of the nature of ozone pollution in the region and subsequently reduce the uncertainties in the diagnosis of high ozone episodes in the Paso del Norte region.

1. Introduction

The Emission Inventory Improvement Plan (EIIP) prepared by the UTEP Rider 8 team for the El Paso Metropolitan Planning Organization (EPMPO) identified six sources where the emissions inventory could be improved (Yang et al, 2011):

- Light duty and heavy duty vehicles at the El Paso-Juarez international ports of entry;
- Aircraft, auxiliary power units, and airport ground support equipment;
- Locomotives;
- Tactical operations at Ft. Bliss Military Reservation;
- Extended idling of heavy duty diesel vehicles at truck stops and rest areas; and
- Dry cleaners.

The sources were selected for various reasons. Emissions of ozone precursors from these sources are significant in their respective categories. For example, NOx emissions from locomotives and commercial aircraft are in the top ten among various nonroad mobile sources. Review of previous inventories prepared by TCEQ revealed discrepancies in NOx emission estimates among different years. Pollutant emissions at the 3 Ports of Entry (POEs) between El Paso and Cd. Juarez, the tactical operations at Ft Bliss, and extended idling of heavy duty vehicles at truck stops and rest areas in El Paso were not reported in TCEQ's archived emission inventories. They are believed to contribute significantly to the formation of ozone in the region given the known magnitude of activities in each case.

In addition, the selected emission sources are located in the high ozone concentration zones in El Paso. Figure 1 shows the locations of some of these emission sources and the distribution of simulated hourly ozone concentrations in El Paso at 2 PM MST on June 18, 2006 (TCEQ). The annual maximum 8-hour average ozone concentration in El Paso occurred on this day. An update and inclusion of these 5 emission sources in the photochemical air quality modeling will improve the accuracy of the emission inventories and, subsequently, reduce the uncertainties in the diagnosis of high ozone episode in the Paso del Norte region.

Furthermore, the regulation potential of each source was carefully considered. Five sources among the six identified in the EIIP were confirmed by El Paso MPO to be potential targets of future control strategies. The emission inventory improvement for dry cleaners was therefore dropped in this perspective.

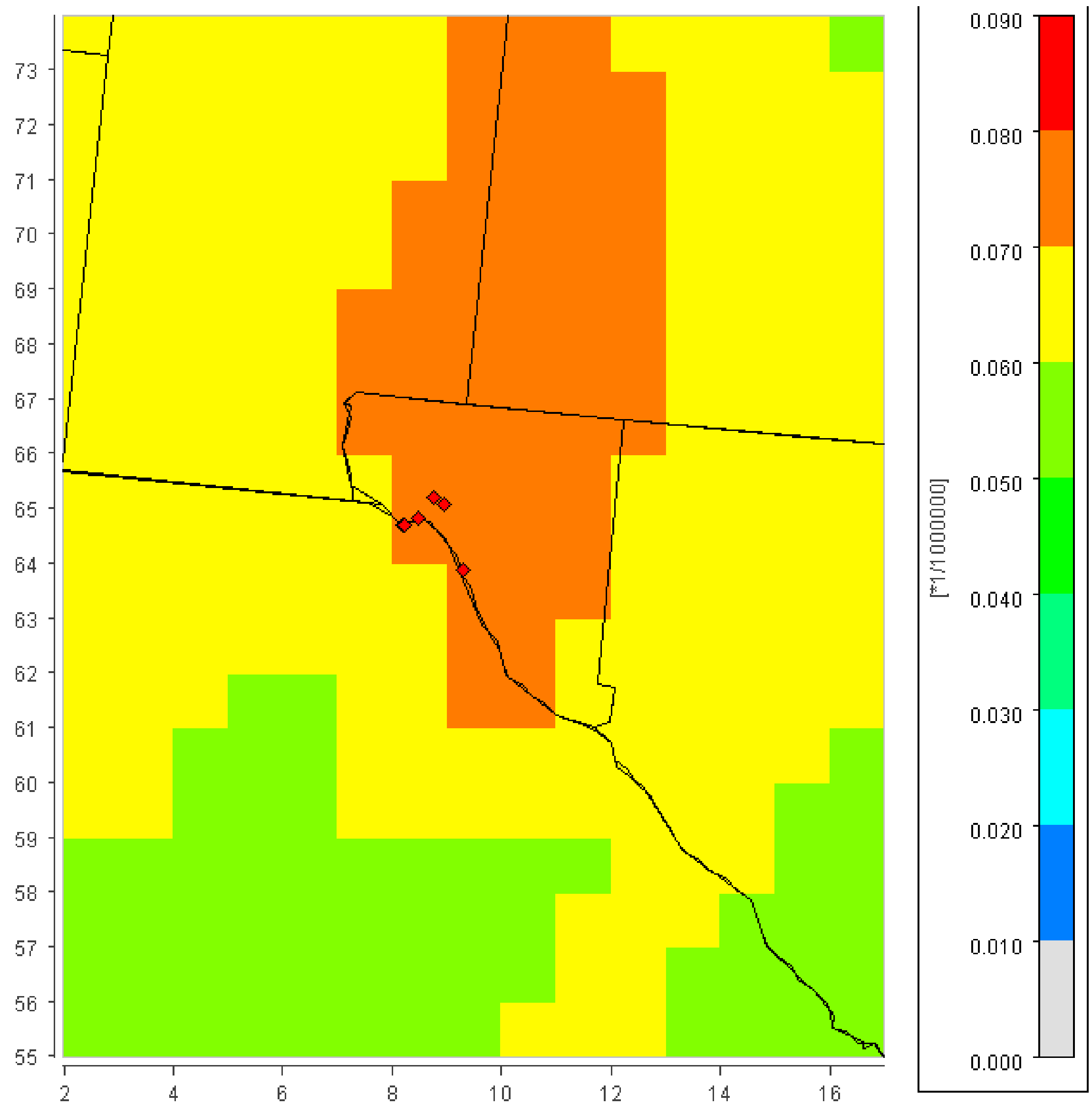

Figure 1 Distribution of hourly ozone concentration (ppm) at 2 PM Mountain Standard Time on June 18, 2006. The CAMx photochemical simulation was provided by TCEQ. The approximate locations of some of the selected sources are overlapped on the distribution plot, including the El Paso international POEs, El Paso International Airport, and Fort Bliss. The horizontal and vertical indices are grid numbers on the 12 km domain.

The general methodology of emission improvement consists of collecting and processing activities and emission factors for each source. For POEs and truck stops, the U.S. EPA MOtor Vehicle Emission Simulator (MOVES2010b) was applied to derive emission factors. For airport, emissions were estimated with the Emissions and Dispersion Modeling System (EDMS), which is preferred by the Federal Aviation Administration (FAA) for air quality analyses at aviation facilities. Two locomotive entities with major operations in El Paso provided emissions together with activities and emission factors for line and yard operations. Ft. Bliss provided emissions of tactical operations as well. The emissions of those sources were reviewed before incorporation into the improved inventory.

2. International Port of Entry Emissions

El Paso has four international POEs bordering its sister city of Cd. Juárez, Chihuahua, Mexico: Bridge of the Americas (BOTA); Ysleta International Bridge (Zaragoza); Paso Del Norte Bridge (PdN); and Stanton Street Bridge. Table 1 lists the geographic coordinates of each bridge in order to be processed as point sources in the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System or Emissions Processing System Version 3 (EPS3). The POEs are also depicted in Figure 1.

Table 1 Locations of the International Ports of Entry in El Paso, Texas

	Longitude	Latitude
Bridge of the Americas (BOTA)	-106.4515	31.7675
Ysleta International Bridge (Zaragoza)	-106.3356	31.6759
Paso Del Norte Bridge (PdN)	-106.4871	31.7514
Stanton Street Bridge	-106.4834	31.7496

Over 40,000 vehicles cross each day into the US from Mexico in El Paso. BOTA has the highest northbound border crossings among the four. The traffic volume at Zaragoza and PdN is about half of BOTA. Stanton Street Bridge primarily handles southbound traffic, but it operates a northbound dedicated commuter lane where waiting queue and emissions are minimal (CBP, Customs and Border Protection, 2012). The queue of northbound traffic may extend for a fraction of 1 kilometer up to 2 kilometers due to the strict border inspection policy on the U.S. side.

This inventory improvement estimated emissions from the waiting or delay of northbound vehicles at the POEs in June 2006. There were minimal delays to the southbound vehicles in 2006. From 2008-2012 U.S. law enforcement agencies have increased security operations for southbound traffic, which may have produced elevations in emissions during this period. The EIIP did not research emissions from queuing of southbound traffic.

Vehicle traffic on the BOTA was carefully examined. The daily and hourly profiles of activities were developed using the 15 minute traffic volume data collected by EPMPO for weekdays and weekends (Saturdays and Sundays, separately) in August 2005. The annual and monthly vehicle crossings at each POE were obtained from CBP. The monthly vehicle crossings on BOTA in June 2006 were scaled by the daily and hourly profiles of August 2005 to derive the hourly traffic volumes of passenger and commercial vehicles on weekdays and weekends. The wait time was simulated by using the tool provided by EPMPO. More technical details on the development of activity data are provided in Appendix 2.

Emission factors by the hour of the day were developed using the U.S. EPA MOVES2010b (Motor Vehicle Emission Simulator). Light-duty and heavy-duty vehicles waiting at the POE were estimated separately since they have different emission factors, which have different queuing times as well, as separate inspection operations are kept for them at the POEs.

Hourly emissions were calculated by incorporating the activity data and emission factors,

$$E_{ijk} = e_{ijk} \times N_{jk} \times T_{jk} \times V$$

where i denotes pollutant type, j denotes vehicle type, k denotes hour, e_{ijk} is the emission factor, N_{jk} is the number of vehicles waiting at the POE, and T_{jk} is the wait time. *V* is the assumed average speed of 2.5 miles/hour, which is the lowest speed bin in MOVES.

Emission factors and hourly emissions were estimated for BOTA. The BOTA receives the most traffic in the El Paso-Ciudad Juarez borderland region and has the most detailed activity records, e.g. the length of waiting queues and delay time on an hourly basis as presented in Appendix 2. Below is a detailed account of MOVES RunSpec and MOVES inputs used in the simulation. The post-processing of MOVES outputs is also described.

MOVES RunSpec

Scale- the scale of the project was selected at the County level and the Emissions Rates were chosen as the calculation type.

Time Spans- emission rates were simulated for the month of June, year of 2006, for both weekends and weekdays for all hours of the day.

Geographic Bounds- under this section, we specified that emission rates would be calculated for El Paso County in the state of Texas.

Vehicles/Equipment- under this section, we selected the on-road vehicles that were modeled. In this panel, the user selects a combination of fuel along with a corresponding vehicle type. In our case we modeled diesel fuel with combination long-haul truck, combination short-haul truck, light commercial truck, and passenger car, single unit long-haul truck, and single unit short-haul truck. Gasoline fuel was modeled with combination short-haul truck, light commercial truck, passenger car, passenger truck, single unit long-haul truck, and single unit short-haul truck.

Road Types- all of the road types were selected, consisting of off-network, rural restricted access, rural unrestricted access, urban restricted access, and urban unrestricted access.

Pollutants and Processes- emission factors were estimated for all criteria pollutants, not just for the ones that intervene in the formation of ozone (VOCs and NOxs). However, to keep the results files at a manageable size, there were three sets of runs to cover all pollutants. In the first set of runs, VOCs, NOxs along with total gaseous hydrocarbons and non-methane hydrocarbons (needed to model VOCs) were the modeled pollutants. In the second set of runs, we modeled carbon monoxide (CO), nitrogen oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and total energy consumption (needed to model SO_2). In the third set of runs, the modeled pollutants were particulate matter both fine and coarse ($PM_{2.5}$ and PM_{10}). At all runs, the selected processes were running exhaust, evaporative permeation and evaporative fuel leaks (for VOCs only) and crankcase running exhaust. In addition, for particulate matter, tirewear and brakewear were included.

Output- in the last panel we specified the name of the output database as well as the units for the results and we specified the vehicle activities for which output will be generated. We selected sources hours, source hours idling, and source hours operating; distance traveled and population were default selections included in our model.

MOVES Inputs

Locality-specific data was input in MOVES MySQL database utilizing the County Data Manager. Since it was assumed that 50 percent of the traffic at the port of entry came from El Paso vehicles and 50 percent came from Juarez vehicles, two age distribution files, and therefore two separate runs for each set, were created. Data for the age distribution of vehicles coming from El Paso, TX was obtained from the Texas Transportation Institute (TTI) for the 2007-1983 period (Table 2); the same registration distribution was assumed for the year 2006. The values provided by TTI were formatted for use in MOBILE6 modeling, therefore, the EPA MOBILE6 to MOVES converter spreadsheet tool was used to transform the values into MOVES input. Age distribution of vehicles specific for Mexico was obtained from the default information provided by MOBILE6 Mexico from TCEQ (Table 3). The age distribution available was from 2002 through 1978 and again a similar distribution was assumed for 2006 for Juarez. MOBILE6 to MOVES spreadsheet converter was used to format the values into adequate MOVES input. The meteorology (temperature and relative humidity) utilized for the model was obtained from TCEQ Continuous Air Monitoring Station (CAMS) 41 for the month of June, 2006 (Table 4). Default data provided by MOVES was used for the remainder of the parameters.

MOVES Output

The emission rate in the table of “rate per distance” was exported from MOVES database for post-processing. Rates per distance, in grams per mile, were generated by MOVES according to a source classification code (SCC), a series of numbers (code) consisting of vehicle type, fuel type, road type and process. It was further specified by hour, pollutant, and day (weekday or weekend). The road type selected to process our results was 11 (Rural Interstate) and only those rates found in average speed bin ID #1 (<2.5 mph) were selected, since that was the speed assumed at the port of entry. A population ratio was calculated from MOVES national default database given in “moves-activity-output” and calculated for every vehicle type. Vehicle types were classified into two groups, passenger and commercial as shown in Table 5.

Table 2 El Paso vehicle registration distribution

Year	LDV	LDT1&2	LDT3&4	HDV2b	HDV3	HDV4	HDV5	HDV6	HDV7	HDV8a	HDV8b	HDBS*	HDBT*	MC
2007	0.05917	0.03092	0.10352	0.06474	0.01468	0.04727	0.05051	0.0142	0.01575	0.00487	0.1269	0.0393	0.0307	0.09876
2006	0.06987	0.0462	0.13405	0.13989	0.06608	0.05455	0.0404	0.02699	0.0315	0.0146	0.11102	0.0734	0.0614	0.17039
2005	0.0674	0.04568	0.11632	0.14889	0.04846	0.02545	0.05556	0.04119	0.00394	0.01703	0.09425	0.0686	0.0614	0.11824
2004	0.06517	0.05484	0.14123	0.09546	0.04552	0.07273	0.0101	0.04119	0.01181	0.03163	0.04263	0.0641	0.0614	0.08086
2003	0.06682	0.05846	0.06979	0.08979	0.03965	0.01455	0.0303	0.01847	0.02362	0.00973	0.05233	0.0599	0.0614	0.09887
2002	0.06898	0.06328	0.07035	0.06758	0.04846	0.03273	0.01515	0.02273	0.02756	0	0.0298	0.0559	0.0614	0.0723
2001	0.06195	0.06781	0.05202	0.06427	0.06021	0.05455	0.05051	0.05114	0.02362	0.02676	0.06647	0.0522	0.0614	0.05068
2000	0.06727	0.06466	0.04021	0.04915	0.06461	0.12723	0.07071	0.08097	0.09841	0.01946	0.10496	0.0488	0.0614	0.04358
1999	0.06013	0.05543	0.0464	0.04679	0.08957	0.09455	0.06061	0.0767	0.0748	0.0292	0.0895	0.0456	0.0614	0.0411
1998	0.0572	0.0541	0.02824	0.03355	0.04552	0.03636	0.0303	0.06392	0.03937	0.03163	0.05859	0.0426	0.0613	0.02748
1997	0.05065	0.05576	0.03399	0.03355	0.04552	0.05818	0.04545	0.04119	0.04724	0.04136	0.04192	0.0398	0.0611	0.02016
1996	0.0423	0.03707	0.01998	0.00851	0.03231	0.06182	0.04545	0.04972	0.01575	0.04623	0.03445	0.0372	0.0607	0.01937
1995	0.04572	0.04294	0.02322	0.02268	0.04846	0.03273	0.05556	0.05682	0.06299	0.06326	0.03657	0.0347	0.0595	0.01363
1994	0.03613	0.04321	0.01626	0.01701	0.04846	0.00364	0.0303	0.04119	0.05118	0.04866	0.02818	0.0324	0.0568	0.01306
1993	0.03098	0.03104	0.01401	0.01371	0.02349	0.02182	0.03535	0.02699	0.04724	0.06083	0.02162	0.0303	0.0511	0.01002
1992	0.02556	0.02476	0.01137	0.00945	0.03084	0.01455	0	0.03409	0.05512	0.05109	0.00576	0.0283	0.0406	0.00676
1991	0.02094	0.021	0.008	0.01323	0.02496	0.01818	0.02525	0.03125	0.04331	0.07299	0.00899	0.0264	0.0254	0.00709
1990	0.01806	0.01966	0.008	0.00992	0.03231	0.03273	0.0404	0.03835	0.04331	0.06569	0.00798	0.0247	0.0121	0.00619
1989	0.01597	0.02045	0.01033	0.01087	0.02203	0.01818	0.0101	0.02131	0.03937	0.07056	0.00737	0.0231	0.0099	0.00315
1988	0.01278	0.02155	0.0067	0.0104	0.02203	0.01455	0.06061	0.01847	0.05118	0.02676	0.00566	0.0216	0.0081	0.00473
1987	0.0097	0.01453	0.00329	0.0052	0.01468	0.01455	0.0101	0.02983	0.01969	0.05353	0.00434	0.0201	0.0066	0.00507
1986	0.00771	0.01675	0.00523	0.01181	0.01468	0.02182	0.0404	0.02983	0.03937	0.04136	0.00414	0.0188	0.0054	0.00957
1985	0.00638	0.01388	0.00493	0.00378	0.01909	0.01091	0.02525	0.0142	0.0315	0.03163	0.00354	0.0176	0.0044	0.00687
1984	0.00493	0.01182	0.00419	0.00378	0.00441	0.01455	0.0202	0.01278	0.01969	0.02676	0.00313	0.0165	0.0037	0.00766
1983+	0.02823	0.0842	0.02837	0.02599	0.09397	0.10182	0.14143	0.11648	0.08268	0.11438	0.0099	0.0781	0.0114	0.06441

Table 3 Mexico vehicle registration distribution

Year	LDV	LDT1&2	LDT3&4	HDV2B-8B	HDBS*	HDBT*	MC*
2002	0.0329	0.0225	0.0221	0.0156	0.0393	0.0307	0.144
2001	0.0562	0.0406	0.0371	0.0451	0.0734	0.0614	0.168
2000	0.0833	0.0829	0.071	0.0404	0.0686	0.0614	0.135
1999	0.068	0.0621	0.0501	0.0387	0.0641	0.0614	0.109
1998	0.0714	0.0771	0.0592	0.0261	0.0599	0.0614	0.088
1997	0.0394	0.0458	0.0337	0.0267	0.0559	0.0614	0.07
1996	0.021	0.0281	0.0201	0.0116	0.0522	0.0614	0.056
1995	0.0319	0.027	0.019	0.026	0.0488	0.0614	0.045
1994	0.0504	0.0659	0.0464	0.0444	0.0456	0.0614	0.036
1993	0.046	0.0823	0.0593	0.0573	0.0426	0.0613	0.029
1992	0.0526	0.0748	0.0561	0.1022	0.0398	0.0611	0.023
1991	0.0398	0.0898	0.0716	0.1027	0.0372	0.0607	0.097
1990	0.0362	0.0683	0.0594	0.0635	0.0347	0.0595	0
1989	0.029	0.052	0.0508	0.0365	0.0324	0.0568	0
1988	0.0228	0.0272	0.0308	0.0202	0.0303	0.0511	0
1987	0.0163	0.0174	0.0234	0.0117	0.0283	0.0406	0
1986	0.0231	0.0211	0.035	0.0196	0.0264	0.0254	0
1985	0.025	0.0193	0.041	0.0265	0.0247	0.0121	0
1984	0.0208	0.011	0.0274	0.0134	0.0231	0.0099	0
1983	0.0175	0.008	0.0194	0.0112	0.0216	0.0081	0
1982	0.0312	0.0144	0.0339	0.0356	0.0201	0.0066	0
1981	0.0295	0.0178	0.0406	0.0346	0.0188	0.0054	0
1980	0.0254	0.0109	0.0241	0.0287	0.0176	0.0044	0
1979	0.0177	0.0099	0.0215	0.021	0.0165	0.0037	0
1978+	0.1125	0.0241	0.047	0.1409	0.0781	0.0114	0

Note: (Table 9 and 10) Denote MOBILE6 defaults*

Table 4 Meteorology for June 2006 from CAMS 41

Hour	Temperature (°F)	Humidity (%)
12:00 AM	80.37	28.55
1:00 AM	79.25	30.14
2:00 AM	77.93	31.75
3:00 AM	76.53	33.41
4:00 AM	75.06	35.03
5:00 AM	74.25	36.26
6:00 AM	75.40	34.71
7:00 AM	77.79	31.73
8:00 AM	80.87	28.88
9:00 AM	84.37	25.08
10:00 AM	87.52	21.90
11:00 AM	89.86	19.54
12:00 PM	91.53	17.76
1:00 PM	92.72	16.38
2:00 PM	93.76	15.09
3:00 PM	94.45	14.54
4:00 PM	93.93	15.22
5:00 PM	93.64	15.42
6:00 PM	92.19	17.19
7:00 PM	90.12	18.81
8:00 PM	87.59	21.51
9:00 PM	85.57	23.49
10:00 PM	83.93	25.13
11:00 PM	82.22	26.81

Emission rates per distance were further processed utilizing queue length (given in vehicles), delay (minutes) and speed (2.5 mph). Queue length and delay were calculated separately and the values used are presented in Appendix 2. Sunday and Saturday information for passenger vehicles was averaged in order to obtain weekend factors, since MOVES results do not differentiate between Saturday and Sunday. Commercial vehicle information was only available for Saturdays, since inspection gates for commercial vehicles are closed on Sundays. Our results were also processed by the factor denominated as 'EP/Juarez ratio' (0.5) taking into account our assumption that 50 percent of the vehicle fleet is from El Paso and 50 percent is from Juarez. Rates per distance were then converted into hourly emissions given in grams in terms of day, hour, pollutant, process, and source classification code (fuel type and vehicle type). Hourly emissions were then summed up for weekdays and weekends and then averaged to obtain a daily average emission in terms of tons per day as shown in Table 6.

Table 5 Vehicle types

Passenger Vehicles	**Commercial Vehicles**
Light Duty Gasoline	Light Duty Gasoline Trucks 2&3
Light Duty Gasoline Trucks 1&2	Heavy Duty Gasoline Vehicles 2B-8B and gasoline buses
Light Duty Diesel Vehicles	Heavy Duty Diesel Vehicles Class 2B
Light Duty Diesel Trucks 1-4	Heavy Duty Diesel Vehicles Class 3, 4, 5
-	Heavy Duty Diesel Vehicles Class 6 & 7
-	Heavy Duty Diesel Vehicles Class 8A & 8B

Table 6 Emissions for criteria pollutants at the BOTA POE

Pollutant	**Average Daily Emissions (tons/day)**
VOC	0.4334
NOx	0.8767
CO	3.7639
SO_2	0.0131
PM_{10}	0.0477
$PM_{2.5}$	0.0290

Emissions at BOTA were then applied to the other bridges taking into consideration only northbound traffic. Table 7 lists the emissions at BOTA, PdN, and Zaragoza. The emissions of the last two POEs were scaled from BOTA using the amount of monthly crossings at each bridge. The daily emissions in Table 7 can be directly processed in EPS3 or SMOKE for air quality modeling. It is noted that NOx emissions at the POEs were significant for the PdN region, which accounts for ~5.5% of the total onroad NOx emissions in El Paso. VOC emissions at the POEs were significant as well, representing for ~2.0% of the total onroad VOC emissions in El Paso. The comparison was made against the TCEQ 2005 emissions, which is summarized in Appendix 1.

Table 7 June 2006 daily emissions at POEs in El Paso (tons/day)

	BOTA		(PdN)		Zaragoza		Total
	passenger	commercial	passenger	commercial	passenger	Commercial	
NOx	0.56	0.40	0.23	0.00	0.22	0.47	**1.89**
VOC	0.41	0.07	0.17	0.00	0.16	0.08	**0.89**
CO	3.63	0.52	1.48	0.00	1.42	0.60	**7.66**
SO2	0.012	0.002	0.005	0.00	0.005	0.002	**0.03**
PM2.5	0.011	0.021	0.005	0.00	0.004	0.024	**0.07**
PM10	0.025	0.027	0.010	0.00	0.010	0.031	**0.10**

The hourly and daily profiles are critical components for emission modeling as well. Since it is the first time emissions at the POEs have been developed for air quality modeling, there are no generic profiles to refer to. They were developed in this study, which are depicted in Figures 2, 3, 4, and 5.

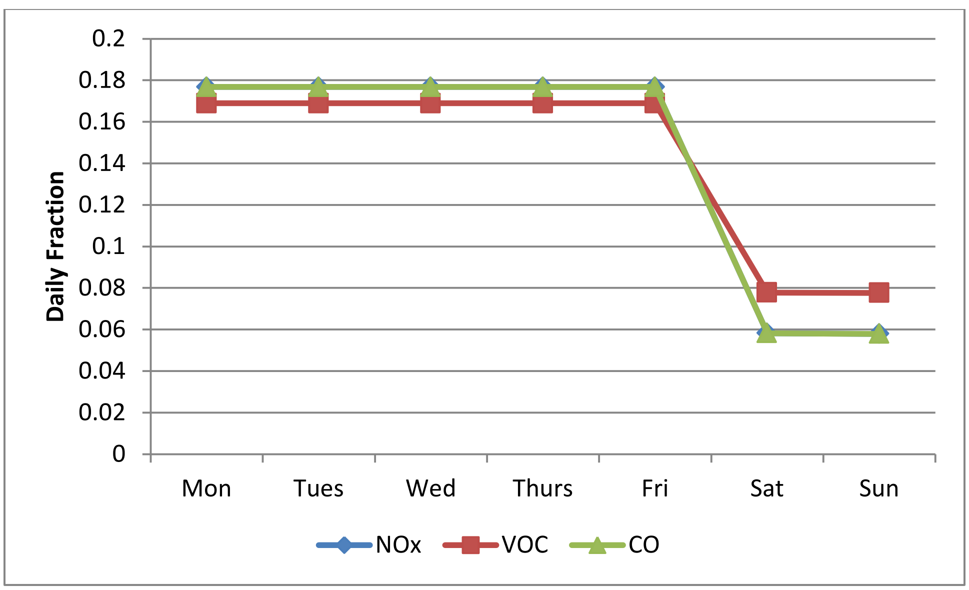

Figure 2 Daily profiles of POE emissions

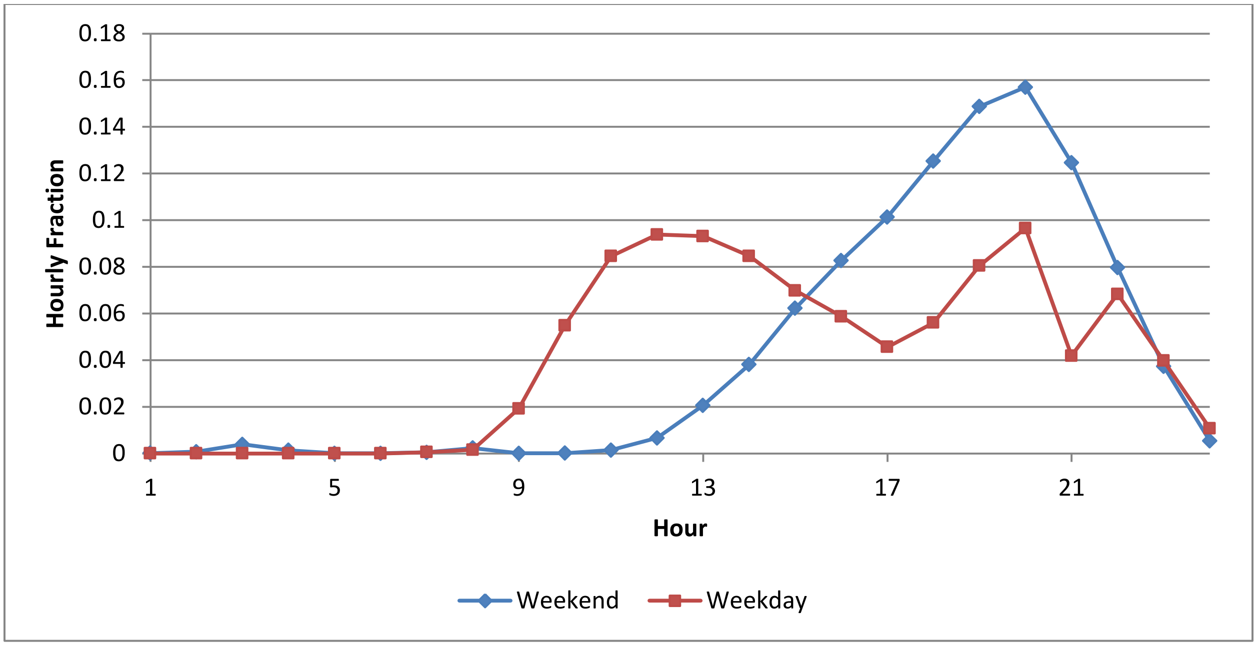

Figure 3 **Hourly profiles of POE NOx emissions**

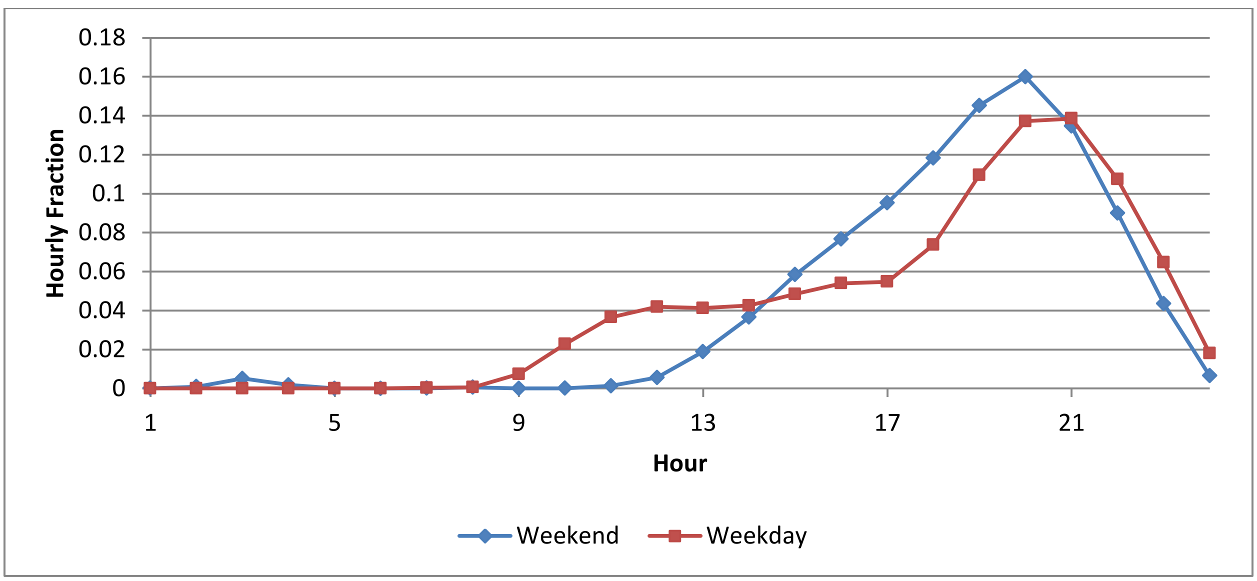

Figure 4 **Hourly profiles of POE VOC emissions**

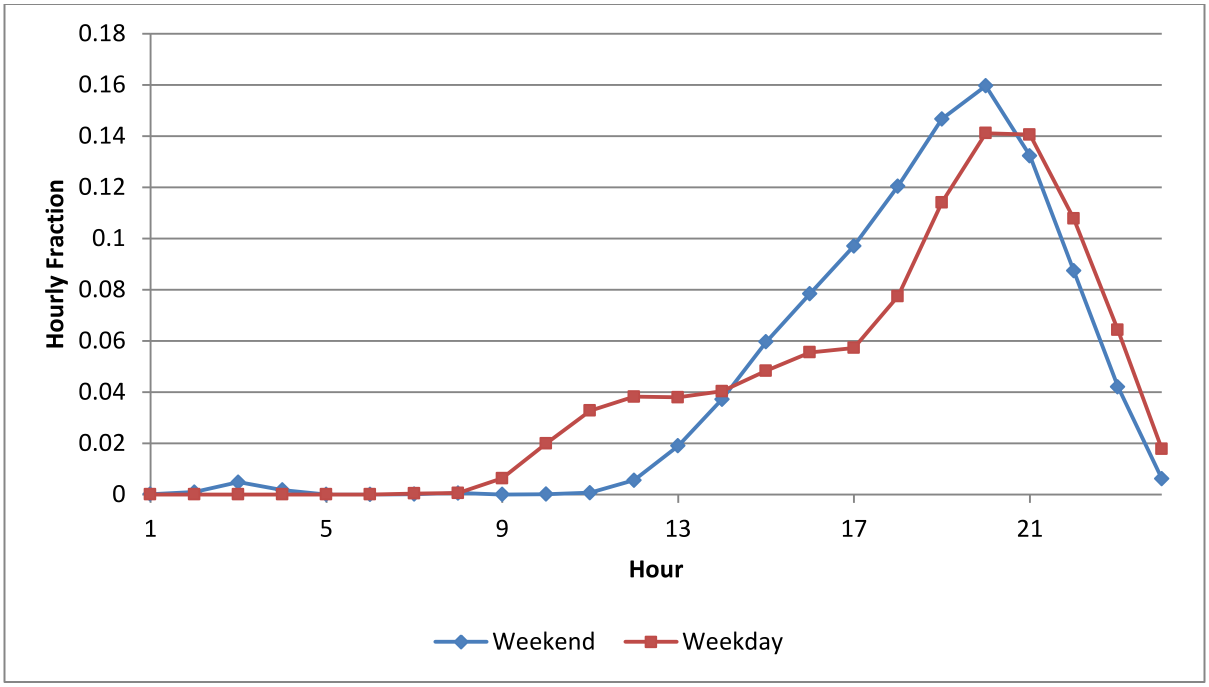

Figure 5 Hourly profiles of POE CO emissions

3. Aircraft, Auxiliary Power Units, and Airport Ground Support Equipment

The airport emissions were estimated using the Emission and Dispersion Modeling System (EDMS 5.1.3). This software is developed and maintained by the Federal Aviation Administration (FAA) and approved by the Environmental Protection Agency (EPA). The model is composed of a series of FORTRAN programs that calculate emissions from aircraft exhaust, ground service vehicles (GSE), auxiliary power units (APUs), aircraft refueling, and fuel storage. It is noted that the emissions from aircraft refueling and fuel storage were included in the area sources of the emission inventory developed by TCEQ. Therefore the emissions from aircraft refueling and fuel storage are not included in this study. The detailed emission calculation methodology and the related default database are documented in the EDMS User Guide. A brief account of the calculation procedure and the sources of user input data files are provided below.

El Paso International Airport (ELP) is the primary commercial airport in El Paso. It serves the tri-regions of West Texas, southern New Mexico, and Northern Mexico, making it an important transportation center between the U.S. and Mexico. ELP is located six miles east of downtown El Paso, 1.7 miles north of Interstate Hwy. 10, and situated near the US-Mexico border. With three runways and an estimate of 3 million passengers in 2011, ELP is served by major U.S. airlines offering direct flights to many major U.S. hubs with connections around the world.

Aircraft exhaust emissions were calculated on the basis of airport operations in terms of the landing and takeoff (LTO) cycle. Airport operations were collected or projected in the El Paso International Airport Master Plan Update Volume 1 (2005). Information of annual, monthly, and hourly operation distributions as well as fleet mix for commercial aviation is available from the master plan. As the fleet mix in 2006 is not provided in the master plan, linear interpolation was used to calculate this value between 2004 and 2009. The LTO of general aviation was calculated by subtracting commercial aircraft LTO from total LTO. The results are shown in Table 8.

Table 8 Fleet Mix at El Paso International Airport in 2006

Aircraft	Departures	LTO
B737-800	3	6
B727-200	0	0
A320	43	86
B727	0	0
B737	140	280
MD83	474	948
B737-300/700	10461	20922
MD80	2667	5334
A-319	302	604
B737-500	5872	11744
B737-200	0	0
A-318	7	14
F-100	0	0
General aviation	N/A	56788
Total LTO	N/A	96726

Emission rates per LTO were calculated based on mode of operation, the duration of each operating mode, the fuel flow/consumption rate, and the emission factor specific to engine design factors. There are five operation modes in a LTO: approach, taxi/idle-in, taxi/idle-out, takeoff, and climbout. The emission factors in EDMS were given for each operating mode for specific engine models, with the fuel flow rate listed as well. The engines used on each aircraft type were determined through the aircraft/engine cross-reference file, which also provides information regarding the number of engines on an aircraft type. The duration of each operating mode is provided according to the aircraft category codes. For some types of the aircrafts not existed in the list of EDMS, we simply used the first item of these series or categories. EDMS uses the following equation to estimate aircraft emissions:

$$E_{ijl} = \Sigma\ T_k \times NE_{jl} \times (FF_{jlk} / 1000) \times (EI_{ijlk}) \times LTO_{jl}$$

where:

E_{ijl} = Emission of pollutant i in pounds produced by the aircraft make j and model l

T_k = Operating time in mode k (min)

NE_{jl} = Number of engines associated with aircraft make j and model l

FF_{jlk} = Fuel flow for individual engine used on aircraft make type j and model l operating in mode k (lbs/min)

EI_{ijlk} = Emission index for pollutant i for each engine associated with aircraft make j and model l operating in mode k (lbs of pollutant /1,000 lbs of fuel)

i = Pollutant (i.e., HC, VOC, CO, NO_x SO_2)

j = Aircraft make (e.g. Boeing, McDonald Douglas, Airbus)

l = Aircraft model (e.g., B-737 300 series)

k = Mode (approach, taxi, takeoff, climbout).

Emissions of general aviation and ground support vehicles (GSE) and auxiliary power units (APUs) were estimated as well, even though the emphasis is on the commercial airports. It is noted that the default emission factors in terms of lb/LTO were used for general aviation, since the information of the fleet mix for general aviation is difficult to obtain. Emissions from GSE and APUs were calculated in EDMS according to the aircraft operations.

Table 9 Emissions of El Paso International Airport in 2006 (tons/year)

Category	Commercial aircrafts	General aviation	GSE	APU	Total
NOx	243.26	11.62	187.77	120.01	562.66
VOC	79.39	39.73	28.65	9.94	157.71
CO	69.02	185.47	558.29	35.00	847.78
SOx	35.79	4.22	17.35	11.37	68.73
PM-10	3.89	N/A	10.09	7.82	21.79
PM-2.5	3.89	N/A	9.77	7.59	21.24

Generic temporal profiles are available for airport emissions in the emission processing system (EPS3 or SMOKE). Since this study obtains relevant information in the master plan, the monthly and hourly profiles of airport operations were developed as well based on the collected information. Temporal profiles are depicted in Figure 6 and Figure 7.

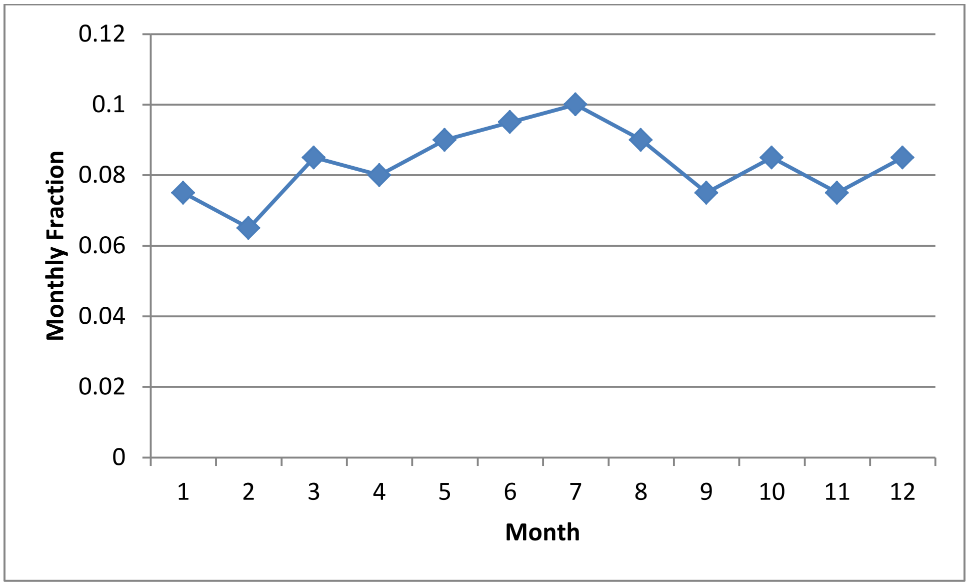

Figure 6 Monthly profiles of airport operations

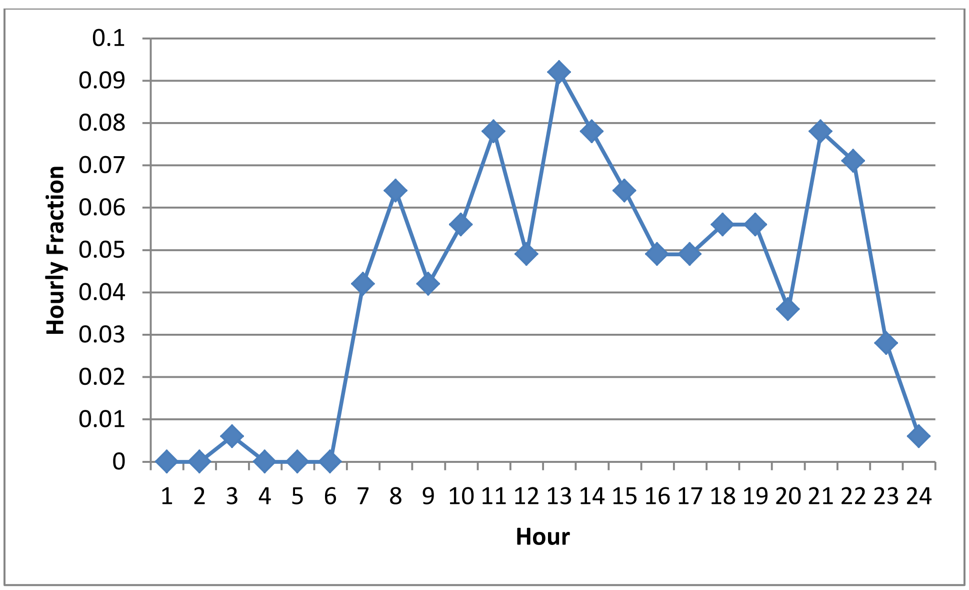

Figure 7 Hourly profiles of airport operations

4. Locomotives

Locomotive emissions are one of the major nonroad mobile sources in El Paso and predicted to increase several fold in the future. Union Pacific (UP) and the Burlington-Northern Santa-Fe (BNSF), two of the three Class I railways operating in Texas, have a major presence in El Paso. El Paso is the regional hub of UP. Construction of a $400 million rail facility in Santa Teresa, New

Mexico was launched by UP in 2011. It will eventually transform Santa Teresa into a new operational hub by 2015 (El Paso Times, 2011). Santa Teresa, which shares the same tri-regional air shed, is a neighboring city to the west of El Paso and shares the same air shed with El Paso.

Gross ton-miles (GTM) for the line haul locomotives and the number of switch engines were provided by UP and BNSF. Gallons of fuel consumed and emissions were provided as well. The activity data and emissions were reviewed by referring to an EPA Guidance document (EPA, 2009), which provides the emission factors of both line haul and switch locomotives.

Both companies cited the 2009 EPA guidance as the source of emission factors to estimate diesel fuel consumption and pollutant emissions. The fuel conversion factors and pollutant emission factors used by each company are similar, but not the same. Table 10 lists the gross ton miles (GTM) of line haul locomotives and the number of switch locomotives operating in El Paso in 2005. It is seen that UP has a much bigger presence in El Paso than BNSF, with an operation about 17 times of the latter. The fuel conversion factors and pollutant emission factors are also listed.

Table 10 2005 Locomotive activities in El Paso, Texas and emission factors (g/gal)

	Union Pacific		BNSF	
	Line Haul	Switch	Line Haul	Switch
Activity	3.35E+09 (GTM)	9.83	1.96E+08 (GTM)	1
Fuel Conversion Factor	771.60 (GTM/gallon)	82,490 (gallon/switcher)	756.70 (GTM/gallon)	50,000 (gallon/switcher)
NOx	180.0	250.0	199.8	199.8
HC	9.5	15.0	10.4	10.4
CO	27.4	27.4	26.6	27.82
PM	6.4	6.5	6.6	6.6

Table 11 lists the 2005 locomotive emissions in El Paso. When compared with the 2005 emissions prepared by TCEQ, it is found that NOx emissions from diesel locomotive equipment (including line haul and switch) are nearly doubled in this inventory improvement study. With an annual total NOx emission of 1136.5 tons, locomotive becomes the top emission source in the nonroad category, which contributes ~40% of total nonroad NOx emissions and ~5% of overall NOx emissions in El Paso. The UTEP EIIP team will continue to work with UP to verify the activity and emissions in El Paso, Texas.

Table 11 2005 locomotive emissions in El Paso, Texas (tons/year)

	Union Pacific		BNSF		Total
	Line Haul	Switch	Line Haul	Switch	
NOx	860.41	208.15	56.93	11.01	1136.50
HC	45.41	12.49	2.96	0.57	61.43
CO	130.97	22.81	7.58	1.53	162.90
PM	30.59	5.41	1.88	0.36	38.24

5. Tactical operations at Ft Bliss Military Reservation

Ft. Bliss, Texas may be considered a “city within a city”. While Ft. Bliss submits an annual point source EI report, emissions generated by tactical operations in northeast El Paso County, Texas and south-central Otero County, New Mexico remain un-quantified. Emissions from several thousand motorized diesel-fueled vehicles and diesel generators produce a large amount of NOx and VOC emissions that should be quantified.

This emission improvement collected and reviewed emissions from tactical operations at Ft. Bliss Military Reservation prepared by their environmental office. Information regarding the spatial and temporal distributions of the emissions was also provided. Table 12 lists the tactical emissions reported for Ft. Bliss.

There are concerns associated with identifying Ft. Bliss as a point source of tactical emissions. For instance, we are not certain whether a point source is an adequate representation for the emissions from the base. Furthermore, it may be inappropriate to concentrate all emissions at a point in the photochemical model given the facility spans over 600 square miles. The collected information indicates that 20% of the emissions occur on the Texas side, and 80% on the New Mexico side of the Military Reservation; and emissions are evenly distributed over Ft. Bliss. As such, it is more appropriate to treat the tactical emissions in Ft Bliss as an area source.

Appropriate hourly, daily, and monthly profiles can be developed based on the collected information. It was reported that the tactical operations are evenly distributed over 12 months and 7 days each week; and they occur during the day and are evenly distributed over the day hours (Fort Bliss, 2012).

Table 12 2005 emissions from tactical operations at Fort Bliss (tons/year)

NOx	HC	CO	SO2	PM10
188.48	38.20	68.26	1.85	8.96

6. Heavy Duty Truck Extended Idling Emissions

Section 108 (f)(xi) of the 1990 Clean Air Act Amendment defines "programs to control extended idling of vehicles" as a candidate transportation control measure. The idea is that vehicular emissions can be reduced by eliminating vehicle idling, either by turning the engine off while the vehicle is stopped or by limiting the periods of time during which a vehicle must be stopped and remain idling. Truck drivers tend to “hotel” at truck stops in order to remain with their trucks whether they drive “company trucks” owned by a corporation or “owner operated” which are owned by individuals.

TCEQ conducted a comprehensive study of heavy duty diesel vehicle (HDDV) extended idling emissions in 2004 (TCEQ, 2004). We used a methodology that is similar to the one used in the 2004 TCEQ study. This truck stop assessment includes updates in emission factors and activities for the Paso del Norte region. Emission factors were developed using the U.S. EPA MOVES2010a. Field surveys were performed to obtain the necessary information from major truck stops in El Paso. In addition, our study included counting the truck refrigeration units (TRU) attached to trailers and operational at the time of the survey.

El Paso County has 7 major truck stops. 3 truck stops are located in the southeast sector and 4 are located in the northwest sector. Table 13 lists the regional truck stops, their locations (the I-10 Exit where the truck stop is located), geographic coordinates (which are helpful for future modeling), and the number of truck parking spaces reported at both the company websites and/or the website www.truckstopsonlinecom. It should be noted that one of the truck stops tended to be filled beyond the stated capacity on several evenings causing overflow parking to occur on streets exiting the facility.

It should also be noted that 3 of the truck stops, all located at Exit 37, have at one time operated truck-stop electrification systems (TSE). TSEs are a method of providing climate control and entertainment systems such as television or Internet into the HDDV. The purpose of the TSE is to allow the driver to enjoy a climate controlled environment and entertainment without relying on back-up power provided by truck engine idling.

Truck counting was conducted by a 2-person team in a vehicle driven along the rows of trucks at the truck stop. In-vehicle counting was preferred in our field study for workers’ health and safety concerns (e.g., avoid running into HDDVs in motion or reduce unnecessary encounters with potentially dangerous people or unexpected potentially hazardous events). Hand-held “clicking counters” were used to count HDDVs at the truck stop, idling HDDVs, and operational TRUs. One team member counted idling HDDVs and operational TRUs while the driver counted all the parked trucks. Vehicle counting was conducted during 11 evenings and 4 daytime periods at different hours of the day and the data was separated into A.M. and P.M. events.

One of the truck stops completely removed the TSEs while the other two truck stops maintain the TSE in place. However, at these two truck stops the TSE appliances (climate control and entertainment systems) are no longer functional due to removal of the ducting system and cables connecting the climate control to the appliance inserted into the truck cab. The 4 truck stops in northwest El Paso County and the 2 in Doña Ana County do not deploy TSEs. It is our perception that the truck stops no longer provide the TSE service in order to sell fuel given a truck may consume up to 6 gallons of diesel per hour of operation at high idle. However, El Paso County is currently in attainment of the NAAQS therefore such emissions reduction technologies are no longer needed to help reduce emissions when such emissions reductions are currently not required.

Table 13 Major truck stops in El Paso County, Texas & Doña Ana County, NM

Name	Address	City	State	Spaces	Lat	Lon
National Truck Stop	I-10 Exit 155	Vado	NM	85	32.126	-106.642
Sunmart #675	I-10 Exit 155	Vado	NM	85	32.124	-106.641
Flying J Travel Plaza #724	I-10 Exit 0	Anthony	TX	176	31.997	-106.579
Love's Travel Stops #447	I-10 Exit 0	Anthony	TX	100	31.997	-106.581
Pilot Travel Centers #435	I-10 Exit 0	Anthony	TX	100	31.997	-106.586
Airway Chevron	I-10 Exit 25	El Paso	TX	10	31.778	-106.392
Flying J Travel Plaza #728	I-10 Exit 37	El Paso	TX	120	31.661	-106.239
Love's Travel Stops #21	I-10 Exit 37	El Paso	TX	90	31.659	-106.238
Petro El Paso	I-10 Exit 37	El Paso	TX	290	31.659	-106.242
Petro Vinton	I-10 Exit 2	Vinton	TX	65	31.958	-106.58

Source: www.truckstopsonline.com

Altogether, the Paso del Norte region has 1121 spaces available at the local truck stops. This project did not consider parking spaces at the rest areas due to the low number of available spaces and location at the eastern limits of El Paso County. Truck stop parking lots begin to substantially fill during the evening hours and usually reach full capacity at midnight. During the sampling period, evening temperatures were in the mid- to upper-90's during most of the nights when HDDV counting was conducted and the truck stops were at or near full capacity.

TCEQ (2011) and TTI (2003) reported that climate control equipment in the trucks is operated at the driver's discretion based on their preference for personal comfort. As such, the high evening temperature coupled with the heat expelled by the HDDV in a congested parking lot suggested that many HDDVs remained idling with air conditioning equipment activated for the duration of the “hoteling” event at the truck stop. During the early evening counting events many of the non-idling vehicles were vacant indicating the driver was potentially dining in the truck stop, using the other amenities available, or merely visiting with other drivers in the parking lot during which time one would not expect the truck to remain idling. Interviews with drivers were not conducted therefore we could not determine patterns in truck idling or use of truck stop amenities.

Emission factors

Truck emissions factors were obtained by running MOVES2010a based on values obtained for HDDV idling at the international POEs. TRU emissions factors were obtained from a project conducted by NREL in 2010. Table 14 displays the emission factors applied for this study in both grams/hr and tons/hr.

Table 14: HDDV and TRU emissions factors (g/hr)

	EMISSION RATES (g/Hr)		EMISSION RATES (ton/Hr)	
Pollutant	HDDV	TRU	HDDV	TRU
NOx	165.0478	123.34	0.00018193	0.00013596
CO	88.78727	61.8	0.00009787	0.00006812
CO2	9130.54	17975	0.01006453	0.01981371
VOC	55.14567	37.28	0.00006079	0.00004109
PM	2.71965	17.6	0.00000300	0.00001940

Emissions calculations

Truck idling emissions were calculated using the following equation:

$$TTSE_j = R_j \sum_{i=1}^{n} 12_{am}\ x\ C_i\ x\ O\ x\ I \ + \ R_j \sum_{i=1}^{n} 12_{pm}\ x\ C_i\ x\ O\ x\ I$$

Where

$TTSE_j$ = Daily total truck stop idling emissions for pollutant *j* (tons / day)

R_j = Emissions rate (tons per hour) for pollutant *j* (NOx or VOC)

12_x = 12 hours with ‘x’ indicating either A.M. or P.M. sampling event

C_i = *Capacity* of truck stop *i*

$\bar{O}$ = Average occupancy rate (%)

$\bar{I}$ = Average idling rate (%)

TRU Emissions were calculated following the similar methodology.

$$TRUE_j = R_j \sum_{i=1}^{n} 12_{am} \; x \, C_i \, x \;\; O \; x \; I \;\; + \;\; R_j \sum_{i=1}^{n} 12_{pm} \; x \, C_i \, x \;\; O \; x \; I$$

Where

$TRUE_j$	=	Daily total emissions of pollutant *j* from truck refrigeration unit (tons / day)
R_j	=	Emissions rate (tons per hour) for pollutant *j* (NOx or VOC)
12x	=	12 hours with ‘x’ indicating either A.M. or P.M. sampling event
C_i	=	Capacity of truck stop i
$\bar{O}$	=	Average occupancy rate (%)
$\bar{I}$	=	Average operational TRU rate (%)

Two sampling periods were undertaken, one representing A.M. and the other representing a P.M. sampling period. For purposes of this study we divided the day into two 12-hour periods. A.M. sampling considers an average occupancy rate for the truck stops assessed during the 4 surveys conducted during the mornings. The P.M. sampling period considers the average occupancy rate for truck stops during the 11 evening survey events.

For purposes of this study the A.M. and P.M. events were established at 5 A.M – 5 P.M. and 5 P.M. - 5 A.M. for A.M. and P.M. emissions calculations, respectively. The purpose for these time delineations is truck stop parking lots begin to fill at an accelerated pace at 5 P.M. and are at or near capacity by midnight. The assumption is also established that all truck drivers comply with the federally mandated 10 hour rest period. Trucks arriving by 5 P.M. will usually depart by 5 A.M. the following morning.

Table 15 summarizes the percentage of usage at the truck stops. The rate of operational TRU appliances was essentially equal between A.M. and P.M. surveys. Identifying operational TRUs was conducted by observing an illuminated temperature gauge. An illuminated light bulb is on when the equipment (TRU) is operating and the unit has a distinct hum when the diesel engine operating the refrigeration unit is active.

Table 16 presents total truck stop emissions estimated by extending the averaged emissions from the surveyed facilities for both idling trucks and operational TRUs over the 7 truck stops in the Paso del Norte region.

Table 15 Truck stop observations

Observation Parameter	%
Average A.M. Occupancy Rate (%)	40
Average P.M. Occupancy Rate (%)	94
Average A.M. Truck Idling Rate (%)	69
Average A.M. Truck Idling Rate (%)	78
Average A.M. Operational TRU Rate (%)	12.3
Average P.M. Operational TRU Rate (%)	13.3

Table 16 NOx and VOC (tons per day) emissions from area truck stops

Pollutant	Avg. A.M. HDDV	Avg. P.M. HDDV	Avg. A.M. TRU	Avg. P.M. TRU	Total Emissions (tpd)
VOC	0.226	0.599	0.041	0.103	0.969
NOx	0.207	1.794	0.121	0.310	2.432

Discussion

This is one of the 1st truck stop emissions inventories to consider TRU emissions. The purpose of including TRU emissions was that this source was identified as a contributor (albeit minimally) of air pollution in the Paso del Norte region and, therefore, should be considered in the ozone formation photochemical models, especially when the magnitude of the emissions have not been quantified. It was later found that, overall, truck stop emissions contribute minimally to regional air pollution compared to the international POEs where over 3,000 truck crossings occur daily. The impact of the emissions from the trucks crossing the border and traveling through the city of El Paso on the Paso del Norte air quality is orders of magnitude higher than that made by the emissions from the truck stops, especially when the primary locations of these truck stops are on the outskirts of the city.

7. Summary

This report provides emission estimates for five sources previously identified in the Emission Inventory Improvement Plan (Li et al 2011):

- Light duty and heavy duty vehicles at the El Paso-Juarez international ports of entry;
- Aircraft, auxiliary power units, and airport ground support equipment;
- Locomotives;

- Tactical operations at Ft. Bliss Military Reservation; and
- Extended idling of heavy duty diesel vehicles at truck stops and rest areas

Among the four international POEs, the Bridge of the Americas (BOTA) has the highest northbound border crossings. The northbound traffic volume at BOTA is approximately the same as the sum of that for the two other major POEs (Zaragoza and PdN Bridges). Emissions from the Stanton Street Bridge were not considered for emission inventory improvement because it is primarily a pedestrian bridge with limited volume of northbound traffic. Traffic emissions at the BOTA were estimated for 2006 and used as the surrogate for emissions from the other two POEs in El Paso. The Motor Vehicle Emission Simulator (MOVES2010b) and the BOTA Queue Analysis Tool (BQAT) software were utilized for estimating average daily and hourly volatile organic compounds (VOCs), nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide (SO_2), coarse particulate matter (PM_{10}) and fine particulate matter ($PM_{2.5}$) emissions. Among the six pollutants, NOx emissions at the POEs were found to be significant for the PdN region, which accounts for approximately 5.5% of the total onroad NOx emissions in El Paso. VOC emissions at the POEs were also found significant, accounted for approximately 2.0% of the total onroad VOC emissions in El Paso.

Emissions from the El Paso International Airport were estimated using the Emission and Dispersion Modeling System (EDMS 5.1.3). It is noted that the emissions from aircraft refueling and fuel storage were included in the area sources of the emission inventory developed by TCEQ. Therefore the emissions from aircraft refueling and fuel storage are not included in this study. Aircraft exhaust emissions were calculated on the basis of airport operations in terms of the landing and takeoff (LTO) cycle. In addition, emissions of general aviation and ground support vehicles (GSE) and auxiliary power units (APUs) were estimated, even though the emphasis is on the commercial airports. Commercial airport emissions in El Paso was found significant for NOx, approximately 4.5% of the total onroad NOx emissions in El Paso whereas VOC emissions were modest at approximately 0.9% of the total onroad VOC emissions in El Paso.

Locomotive emissions inventory was obtained from Union Pacific (UP) and Burlington-Northern Santa-Fe (BNSF), two of the three Class I railways operating in Texas. All related information was provided by the two companies. It was found that NOx emissions from locomotive could account for approximately 40% of total nonroad NOx emissions or 5% of the total onroad NOx emissions in El Paso.

Emission inventory for the tactical operations at Ft. Bliss Military Reservation was provided by Ft. Bliss. Emissions of NOx and VOCs were judged insignificant compared to the emissions from other sources although there are concerns about whether the emissions reflected accurately the emissions at the facilities and the locations/spatial distribution of these emissions.

Emissions from the truck stops were estimated by conducting a week long study at 3 regional truck stops to quantify the numbers of HDDVs at the truck stop, idling HDDVs, and operational TRUs. Truck emissions factors were obtained by running MOVES2010a based on values obtained for HDDV idling at the international POEs. TRU emissions factors were obtained from a project conducted by NREL in 2010. It was concluded that NOx and VOC emissions from the regional truck were insignificant relative to the overall emissions in the region.

8. References

El Paso Times, 2011, Work starts on Union Pacific rail facility in Santa Teresa.

Fort Bliss, 2012, J. Moncada, personal communication, March 26, 2012.

Li, W.W., Yang, H., Olvera, H., Cheu, K. R.L., Fitzgerald, R., Yang, H. 2011, Emission Inventory Review and Implementation Plan, Draft Final Report to El Paso MPO. the University of Texas at El Paso, 79 pages.

Texas Commission on Environmental Quality, 2011, Characterization of Vehicle Activity and Emissions From Heavy-Duty Diesel Vehicles in Texas.

Texas Transportation Institute, 2003, Heavy Duty Diesel Vehicle (HDDV) Idling Activity and Emission Study, Phase 1: Study Design and Estimation of Magnitude of the Problem.

U.S. Environmental Protection Agency, 2009, Emission Factors for Locomotives, EPA-420-F-09-025.

U.S. Environmental Protection Agency, 2012, Using MOVES to Prepare Emission Inventories in State Implementation Plans and Transportation Conformity, Technical Guidance for MOVES2010, 2010a and 2010b, Table A.2. EPA-420-B-12-028.

U.S. Federal Aviation Administration, 2010, Emissions and Dispersion Modeling System (EDMS) User's Manual, FAA-AEE-07-01.

9. Appendices

Appendix 1: Summary of 2005 TCEQ Emission Inventory

Emissions from current available inventories were processed preliminarily through EPS3. The summary tables are based on the reports generated by EPS3. The data sources include TCEQ TexAER repository and the U.S. EPA NEI database. Emissions of area, nonroad, and noroad sources from El Paso and Hudpeth are extracted from the TexAER system, and the rest emissions are retrieved from the EPA NEI database.

Table 1 Summary of 2005 NOx emissions

2005 NOX Tons/Day				
	Area	NonRoad	OnRoad	Point
El Paso	3.3449	7.8774	34.1893	4.7752
Hudpeth	0.0702	2.6013	4.4568	0
Dona Anna	1.282	2.1742	17.9489	2.3791
Otero	0.4064	0.8988	4.5221	0
Juarez	0.1845	11.0254	24.7427	
Total	5.2879	348.9169	85.8598	7.1543

Table 2 Summary of 2005 VOC emissions

2005 VOC Tons/Day				
	Area	NonRoad	OnRoad	Point
El Paso	22.7611	4.2395	16.6291	0.1202
Hudpeth	0.5701	0.3677	1.4379	0
Dona Anna	6.6389	1.9715	8.8713	0.0592
Otero	2.4243	1.3602	2.11	0
Juarez	19.7366	1.1549	30.2492	
Total	52.131	43.0676	48.6274	0.1794

Table 3 Summary of 2005 CO emissions

2005 CO Tons/Day				
	Area	NonRoad	OnRoad	Point
El Paso	17.5796	61.6893	207.2455	2.5142
Hudpeth	5.0059	1.2719	23.7918	0
Dona Anna	9.248	20.2903	79.3595	0.3801
Otero	2.4335	7.8513	21.1308	0
Juarez	4.0317	5.5599	230.7167	
Total	38.2986	260.2185	464.5743	2.8943

Appendix 2: Bridge of the Americas Port of Entry: Queue Length and Delay Estimation for June 2006 Technical Report

Bridge of the Americas Port of Entry: Queue Length and Delay Estimation for June 2006 Technical Report

Kelvin Cheu, Ph.D., P.E.,
Department of Civil Engineering
The University of Texas at El Paso
500 W. University Ave. El Paso Texas, 79968
Tel: (915) 747-5717
E-mail: rcheu@utep.edu

George Pinal, Transportation Planner
El Paso Metropolitan Planning Organization
10767 Gateway Blvd W Ste. 605 El Paso, TX 79935
Tel: (915) 595-9725 ext. 25
E-mail: gpinal@elpasompo.org

Alicia Romo, E.I.T.
Department of Civil Engineering
The University of Texas at El Paso
500 W. University Ave., El Paso Texas, 79968
Tel: (915) 747-6129
E-mail: aromo2@miners.utep.edu

Table of Contents

I. OBJECTIVE

The objective of this study is to provide viable results pertaining to vehicular queue length and delay for a typical weekday and weekends (Saturday and Sunday) the Bridge of the Americas (BOTA) on June 2006. These results will be used later as inputs to Ozone production estimation at one of the most congested Port of Entry (POE) in the US- Mexican Border.

II. DATA SOURCE

The available data utilized for this research are taken from three sources: El Paso Metropolitan Planning Organization (MPO), Megaradio radio station and U.S. Customs and Border Protection (CBP). Data from El Paso MPO was mainly used for estimation, whereas, Megaradio and CBP data was used to calculate and validate projections of northbound daily crossings: from Juarez to El Paso for 2005 and 2006.

Data from El Paso MPO describes daily arriving volume in 2005 for weekdays, Saturdays, and Sundays. The volumes are given in 15-minute intervals and were collected by Wilbur Smith Associates for MPO. This tool was employed in the Camino Real Corridor Border Improvement Plan (BIP Study) as a tool to describe existing conditions at the Ports of Entry (MPO, 2006a). For this study, data collected in the following days were provided and considered: August 24 and 25, August 20 and 27, and August 21 and 28, to account for daily arrivals for weekdays, Saturdays and Sundays, respectively.

POE queue length reports provided by Megaradio through public radio stations (http://www.megaradio.com.mx/) were mainly utilized to validate the estimated hourly arrival profiles to have a better representation of the northbound crossings. These reports give queue information for pedestrians and private vehicles at all POE using reference markers to inform commuters the congestion status. These reported queue lengths were captured every day of the week for one week and were recorded every fifteen minutes from 6:00 a.m. to 8:00 p.m.

Data from U.S. CBP (http://apps.cbp.gov/bwt/) mainly served as a comparison for the results obtained in the study. This data describe northbound traffic volumes at all the POEs located in Juarez-El Paso Mexican Border. This includes, Paso del Norte, Stanton, Bridge of the Americas, Zaragoza, Fabens and Santa Teresa Port of Entry. This document gives monthly total figures for trucks, buses, privately-owned vehicles, trains, rail containers and pedestrian crossings. Historical data was provided from 2002 to 2010 although only June volumes for 2006 are used for in this case study. For this purpose, only the monthly total volumes at BOTA (northbound) were used. The volumes were broken down to commercial and non-commercial vehicles.

III. METHODOLOGY

This section gives a detailed description for each step in the methodology followed in this study in order to estimate daily northbound crossing volumes in 15-minute intervals for June 2006.

Commercial and non-commercial volume counts for August 2005 provided by MPO were utilized to find average 15-minute volumes for weekdays, Saturday and Sunday. Using two days for each day-of-week category, it was possible to estimate a mean value at every 15 minutes.

Monthly total volumes were estimated by taking into consideration the number of weekdays, Saturdays and Sundays in August 2005. For example, by knowing that there was 23 weekdays, four Saturdays and four Sundays in August 2005, the total monthly volume was obtained by multiplying each daily volume by their corresponding occurrence (See Equations 1 and 2 below). The monthly volume calculated for August 2005 is shown in Table 1.

$$Estimated\ 2005\ Monthly\ Volume\ for\ Non-Commercial\ vehicles = Total\ Daily\ Average\ Volume\ for\ Weekday * 23\ weekdays + Total\ Daily\ Average\ Volume\ for\ Saturday * 4\ Saturdays\ + Total\ Daily\ Average\ Volume\ for\ Sunday * 4\ Sundays \quad \text{Eq. 1}$$

$$Estimated\ 2005\ Monthly\ Volume\ for\ \ Commercial\ vehicles = Total\ Daily\ Average\ Volume\ for\ Weekday * 23\ weekdays + Total\ Daily\ Average\ Volume\ for\ Saturday * 4\ Saturdays \quad \text{Eq. 2}$$

Table 1- Estimated and CBP POE Vehicle Volume for August 2005

	Non-commercial Vehicles (veh/month)	Commercial Vehicles (veh/month)
Weekday	465,520	33,626
Saturday	97,624	2,044
Sunday	88,716	-
TOTAL	651,860	35,670
U.S. CBP POE Crossing volume	708,636	35,907

These figures were compared to those provided by U.S. CBP (MPO, 2009) where monthly totals for August 2005 are recorded as 708,636 veh/month and 35,907 veh/month for non-commercial and commercial vehicles respectively. The differences are partly due to the assumptions used in Equations 1 and 2. It was considered that the estimated values provide an accurate representation and thus, could be used as a reference in later calculations.

Since the CBP data only consists of monthly total northbound volume for commercial and non-commercial vehicles in June 2006, in order to convert the monthly volume into the daily volume of northbound traffic at BOTA, Daily Factors were derived using daily (weekday, Saturday or Sunday) volume divided by the estimated monthly crossings as shown in Equation 3. Later, the daily factor, when multiplied by the monthly volume in June 2006, gave the daily northbound volume in June 2006. The fractions used for each vehicle category during this estimation process are presented in Table 2.

$$Daily\ Factor = \frac{Total\ Daily\ Average\ Volume\ in\ August\ 2005}{Estimated\ Monthly\ Volume\ in\ August\ 2005} \quad \text{Eq. 3}$$

Table 2- Estimated Daily Fraction

	Daily Factor	
	Non-commercial Vehicles	Commercial Vehicles
Weekday	0.03718	0.04099
Saturday	0.03744	0.01433
Sunday	0.03402	-

Since input to the BOTA Queue Analysis Tool (BQAT) software (MPO, 2006b) must be given in 15-minute intervals for 24 continuous hours, the 15-minute volumes were simply obtained by using the average 15-minute traffic profile for August 2005. This profile was obtained by plotting the average daily volume for August 2005 at every 15 minutes for an entire day. Then, a 15-Minute Fraction is used as a reference for the predicted volume for June 2006. The fraction is the ratio of 15-minute volume over the total daily volume as indicated in Equation 4.

$$Average\ 15\min\ Fraction = \frac{15\min Volume}{Total\ Average\ Volume\ in\ August\ 2005} \quad \text{Eq.}$$

In order to calculate the northbound traffic volume for June 2006, the following operations were performed as can be referred in Equations 5 and 6.

$$Daily\ Total\ Volume\ for\ June\ 2006 = Mont\text{□}ly\ Volume\ for\ June\ 2006(CBP) * Daily\ Fraction \quad \text{Eq. 5}$$

$$15\ Minute\ Volume\ for\ June\ 2006 = 15 Minute\ Fraction * Daily\ Total\ Volume\ for\ June\ 2006 \quad \text{Eq.}$$

The same computations were repeated for weekday, Saturday and Sunday, for non-commercial and commercial vehicles. For the case of non-commercial vehicles, further adjustments were performed as described in the following section.

IV. TRAFFIC PROFILE

A. NON-COMMERCIAL VEHICLES

After estimations were performed with the methodology described in the previous section, it was observed that the 15-minute arrival rates for non-commercial vehicles were very high at the end of the day. This was because the 15-minute fractions were derived using the volume counts collected in the last two weeks of August 2005. One possible explanation for the overestimation of vehicle arrival rates between 8:00 p.m. and 12:00 a.m. could be that visitors that spent summer vacations in Juarez were returning from a whole day trips at night. Another possible reason could be shopping of merchandise related to school as scholar articles, uniforms, etc. as special offers are highly advertised during the start of the school year. Because of this unexpected high flow of vehicles at night, a secondary investigation was conducted in order to observe the vehicle arrival profile during a normal day in May 2012. During four days May 7-10,2012, , periodic traffic reports of northbound traffic at BOTA were taken from the information provided by Megaradio public radio (http://www.megaradio.com.mx/) and U.S. CBP (http://apps.cbp.gov/bwt/). As expected, both sources reported that the north bound non-commercial queue lengths or delay began to decline at the end of the evening. Therefore, it was concluded that the volume estimated from 8:00 p.m. until midnight should be reduced by 100 veh/hr from the projected figures. This adjustment was only necessary for non-commercial vehicles since commercial vehicles showed a reasonable volume profile.

The following graphs (Figures 1 to 3) represent the arriving volume for June 2006 that was estimated and adjusted to reflect traffic scenarios, in addition to the volume in August 2005 provided by MPO.

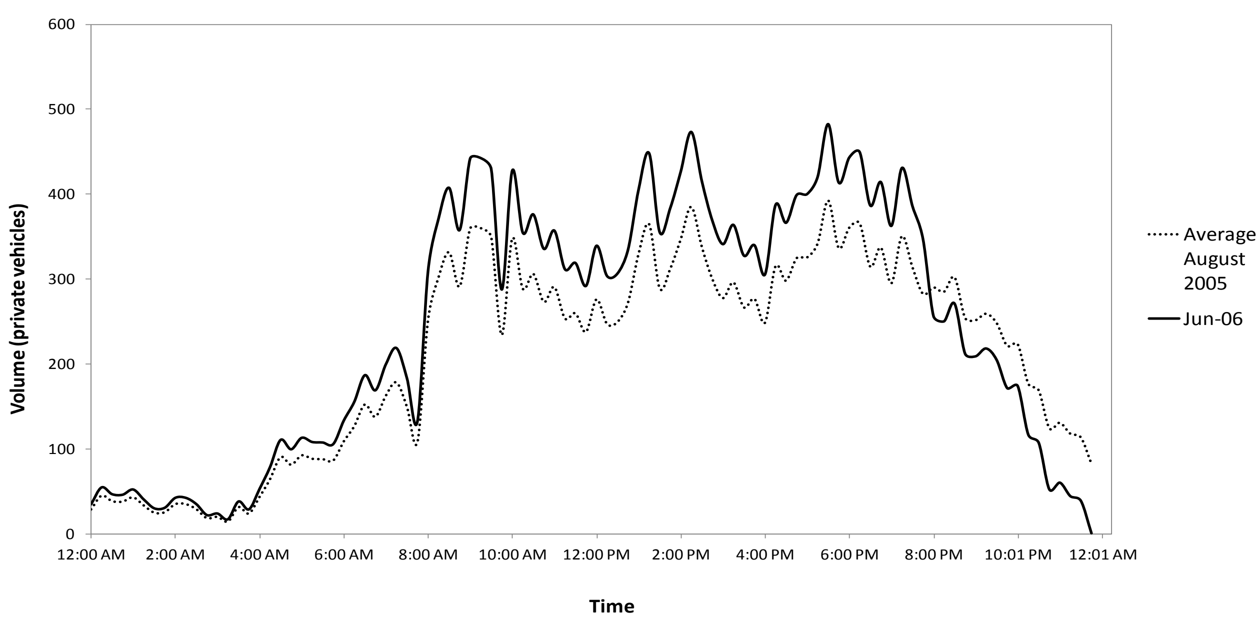

Figure 1- Weekly Private Vehicle Volume Profile

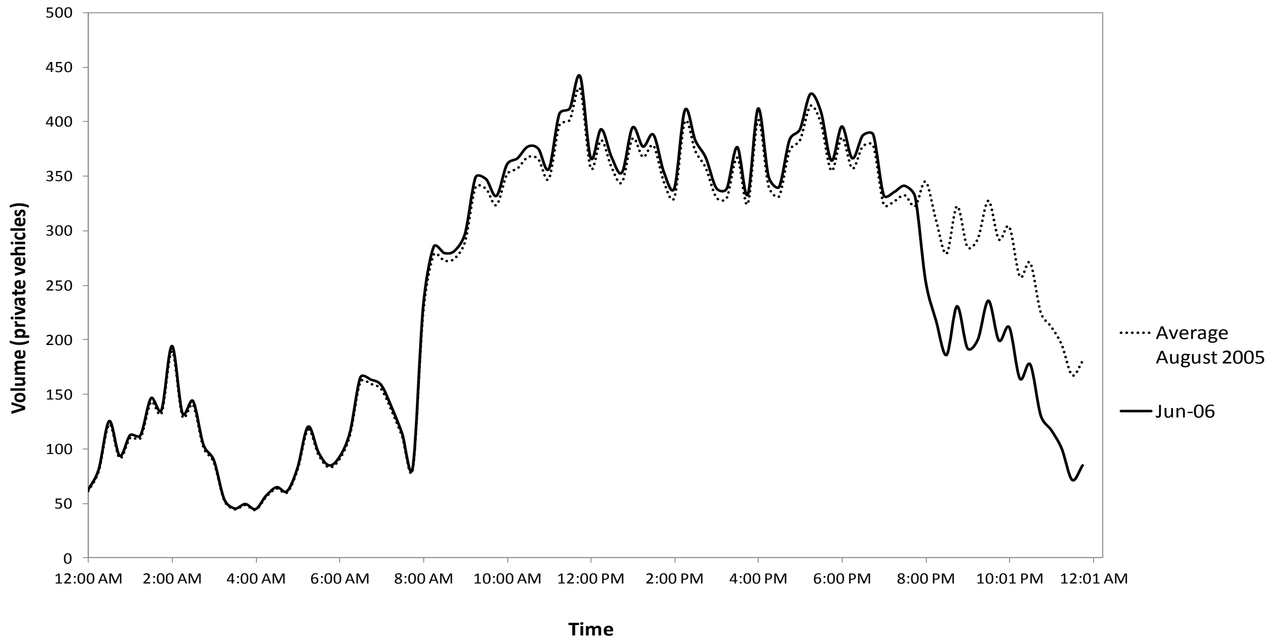

Figure 2- Saturday Private Vehicle Volume Profile

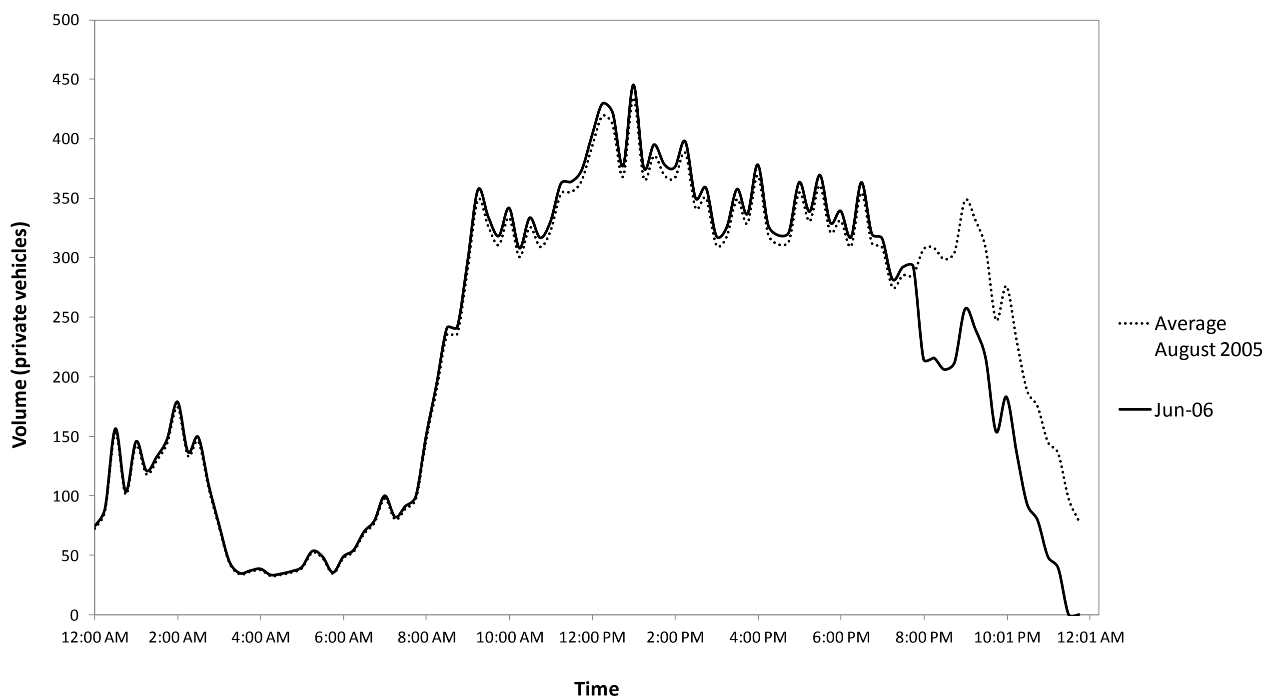

Figure 3- Sunday Private Vehicle Volume Profile

B. COMMERCIAL VEHICLES

Figures 4-5 show the commercial crossing profile for August 2005 and the estimated volume for June 2006. Figure 4 shows the arrival profiles in an average weekday in August 2005 and June

2006; whereas Figure 5 shows the arrival profiles in an average Saturday in August 2005 and June 2006. The BOTA POE is closed for commercial traffic on Sundays.

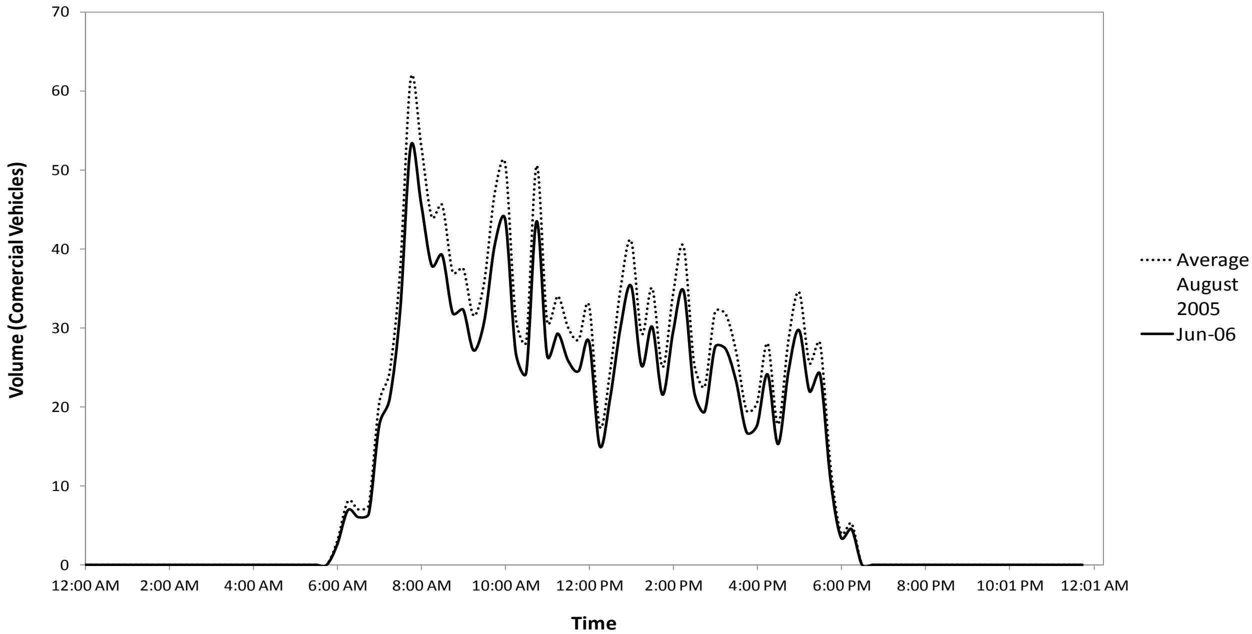

Figure 4- Weekday Commercial Volume Profile

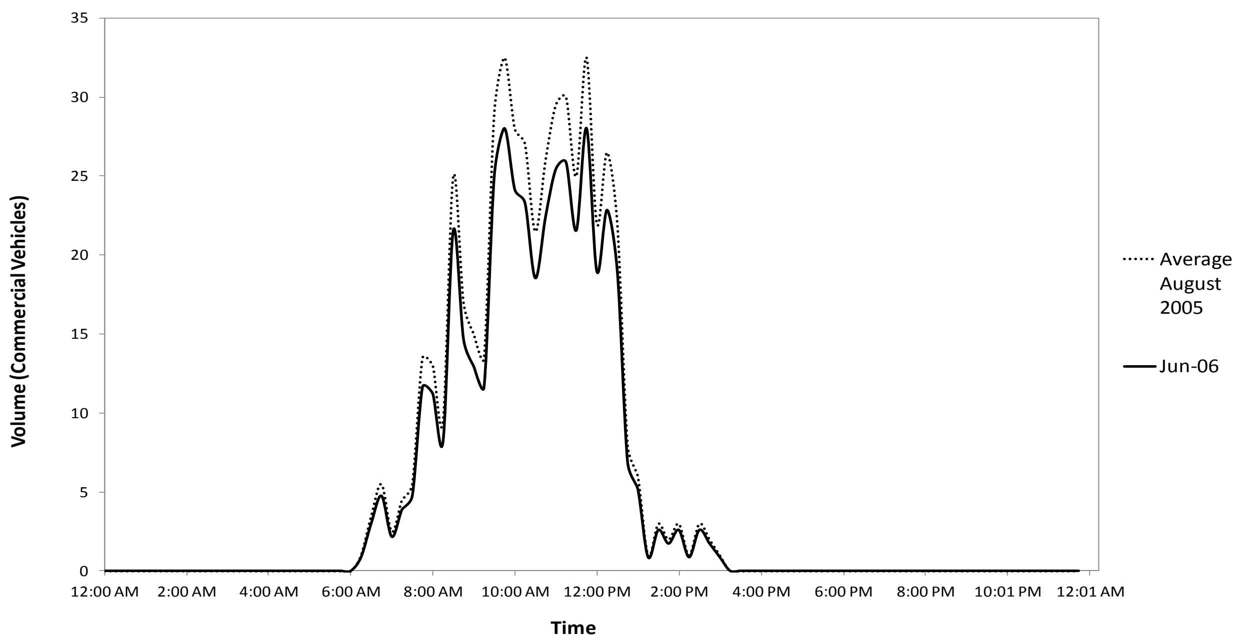

Figure 5- Saturday Commercial Volume Profile

V. QUEUE LENGTH AND TIME DELAY SIMULATION

Queuing and delay scenarios were simulated in order to find their average values per hour during a day. BQAT (MPO, 200b) was used for simulation of delay and queue length at northbound of BOTA POE. This program was developed by Wilbur Smith Associates for MPO, and was used in the preparation of the Camino Real Border Improvement Plan (MPO, 2006). The different cases, i.e., Weekday, Saturday and Sunday, were analyzed and described throughout this section. The results were obtained after input the arriving 15-minute volumes estimated in Section III into the simulation tool. This process was repeated for non-commercial, as well as, for commercial vehicles at the northbound BOTA POE.

A. Parameters used in Non-Commercial Vehicles Simulation

In BQAT, the "discharge rate" (inspection time) was assumed to follow a log-normal distribution. The statistical parameters of inspection time for private vehicles (average duration, standard deviation and maximum inspection time) were considered to match CBP inspections according to MPO. Together, when used with a log-normal distribution, they gave a mode (most frequent occurrences) at 60 seconds. The values for maximum inspection time were 300 seconds, respectively. Figure 6 plots the distribution of the inspection time according to the log-normal distribution.

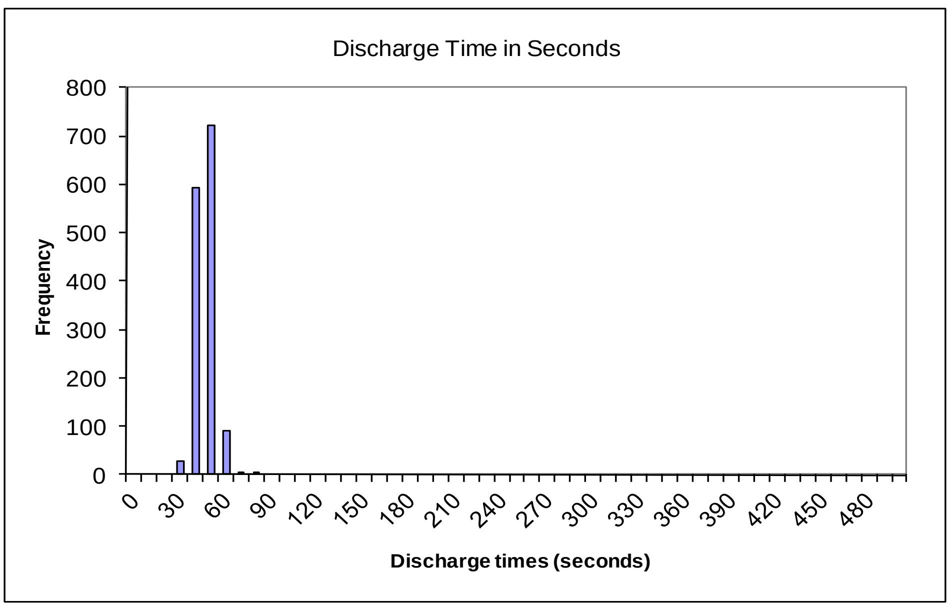

Figure 6 – Discharge Time in seconds for Commercial Vehicles

The BOAT program simulates vehicles joining the queue and leaving the inspection booth every minute. Therefore, the program distributes the 15-minute volumes into each minute's arrivals. The default distribution was Poisson. The use of Poisson distribution implicitly assumes that vehicle arrivals are random; that is, the arriving times are independent of each other. The use of Poisson distribute will occasionally produce unreasonably high number of vehicles that could arrive in one minute. However, during peak hours of the day, vehicle tends to arrive in platoons and no longer in a random fashion. For a more realistic simulation, the BQAT program was modified to have uniform vehicle arrivals within each 15-minute period starting from 4am until midnight.

For this study, five non-commercial inspection booths were considered to operate from 12:00 a.m. until 6:59 a.m. Between 7:00 a.m. to 12:00 a.m., a total of 14 booths stayed opened. This same schedule was applied in weekday and weekends. Each inspection booth was assumed to have inspection time that follow the distribution in Figure 6.

B. Queue Length and Time Delay Results for Non-Commercial Vehicles Simulation

Using the BQAT simulation tool, it was possible to obtain average queue length and delay using the estimated arrivals for June 2006. Tables 3-5 following by corresponding Figures 7-9 demonstrate the simulated queue length hour by hour, in unit of vehicles for weekday, Saturday and Sunday, respectively. Tables 7-8 followed by Figure 10-12 show the delay in minutes for Weekday, Saturday and Sunday. In general, the queue length, as well as, the delay is greater on weekdays than on weekends.

Now, when comparing the lengths of queues form Figures 7-9, Saturday and Sunday portray a smoother curve or less variation as compared to weekday. In addition, on weekdays, the queue length starts to increase rapidly in the late morning as travelers need to cross the border to get to work/school.

The behavior of delay showed in Figures 10-12 corresponds to the variation of queue length for each day. It is interesting though that on weekends, early morning crossings are higher than on weekdays. This can be due to people that go southbound for entertainment on Fridays and Saturdays nights and are coming back next day early morning.

Table 3 - Average Queue Length for Non-Commercial Vehicles on Weekday

Time	Average Queue (non-commercial vehicles)
12:00 AM	0
1:00 AM	1
2:00 AM	1
3:00 AM	0
4:00 AM	1
5:00 AM	4
6:00 AM	81
7:00 AM	43
8:00 AM	87
9:00 AM	436
10:00 AM	685
11:00 AM	822
12:00 PM	832
1:00 PM	1037
2:00 PM	1446
3:00 PM	1704
4:00 PM	1857
5:00 PM	2193
6:00 PM	2673
7:00 PM	2986
8:00 PM	2990
9:00 PM	2638
10:00 PM	2039
11:00 PM	1077

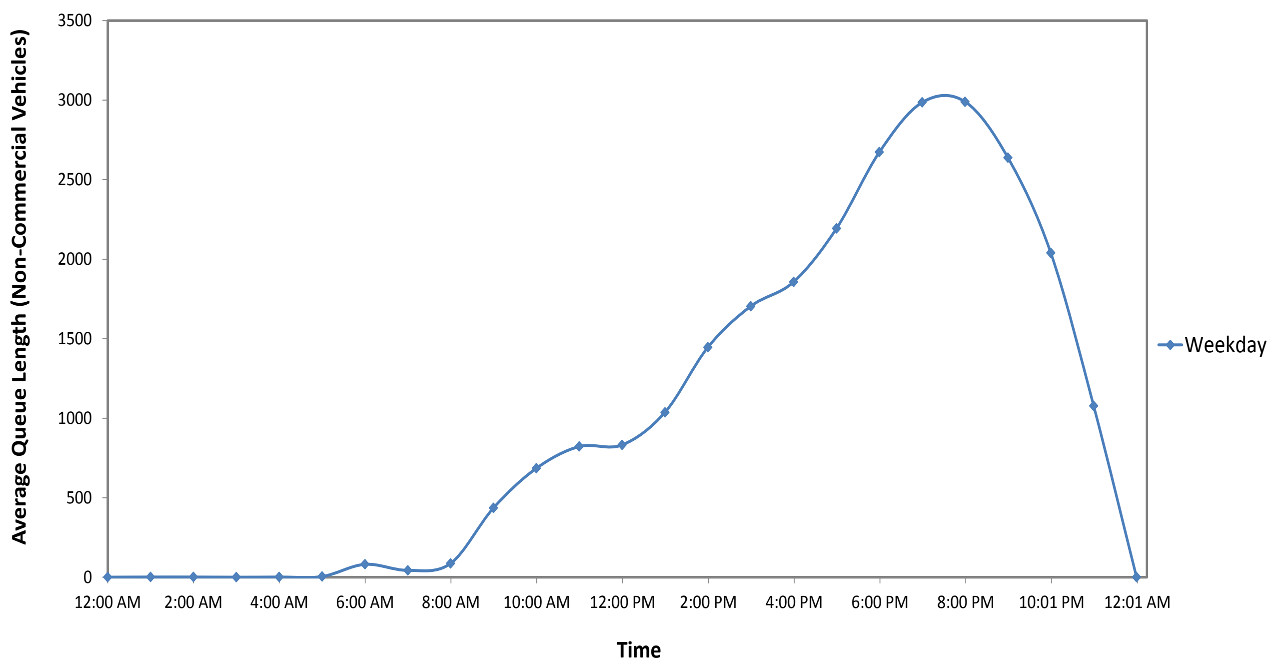

Figure 7 – Weekday Non-Commercial Vehicle Queue

Table 4 - Average Queue Length for Non-Commercial Vehicles on Saturday

Time	Average Queue (non-commercial vehicles)
12:00 AM	14
1:00 AM	59
2:00 AM	190
3:00 AM	86
4:00 AM	0
5:00 AM	4
6:00 AM	28
7:00 AM	8
8:00 AM	1
9:00 AM	45
10:00 AM	225
11:00 AM	517
12:00 PM	864
1:00 PM	1117
2:00 PM	1355
3:00 PM	1560
4:00 PM	1769
5:00 PM	2060
6:00 PM	2329
7:00 PM	2536
8:00 PM	2409
9:00 PM	1994
10:00 PM	1532
11:00 PM	807

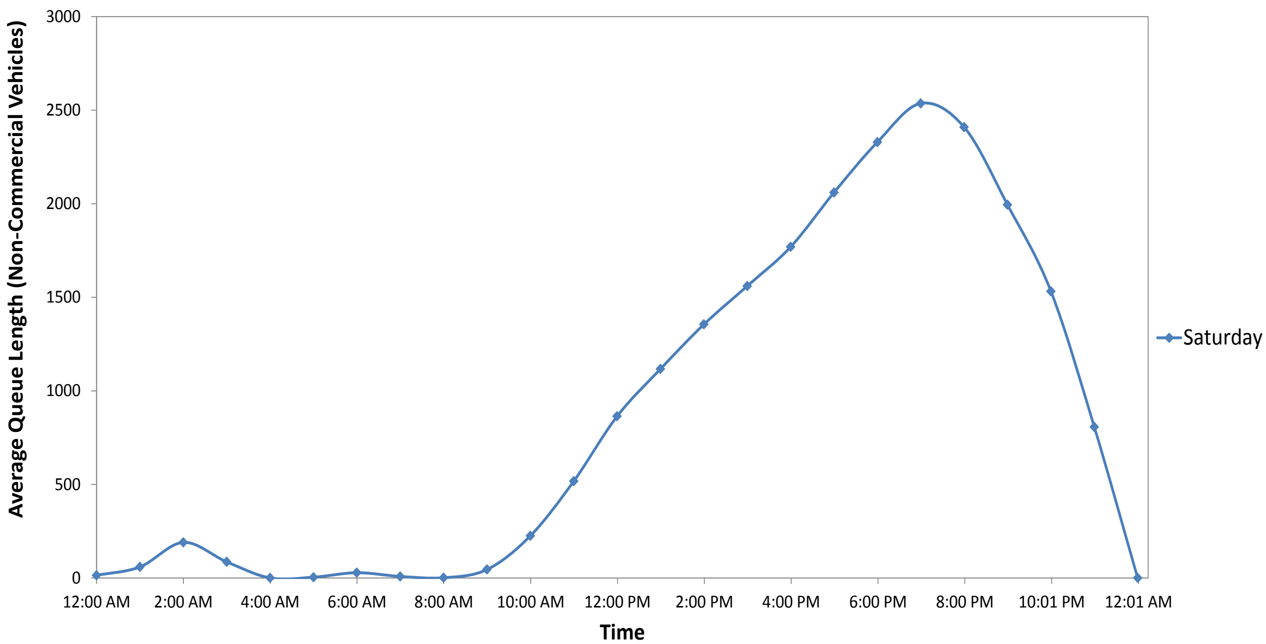

Figure 8 – Saturday Non-Commercial Vehicle Queue

Table 5 - Average Queue Length for Non-Commercial Vehicles on Saturday

Time	Average Queue (non-commercial vehicles)
12:00 AM	14
1:00 AM	59
2:00 AM	190
3:00 AM	86
4:00 AM	0
5:00 AM	4
6:00 AM	28
7:00 AM	8
8:00 AM	1
9:00 AM	45
10:00 AM	225
11:00 AM	517
12:00 PM	864
1:00 PM	1117
2:00 PM	1355
3:00 PM	1560
4:00 PM	1769
5:00 PM	2060
6:00 PM	2329
7:00 PM	2536
8:00 PM	2409
9:00 PM	1994
10:00 PM	1532
11:00 PM	807

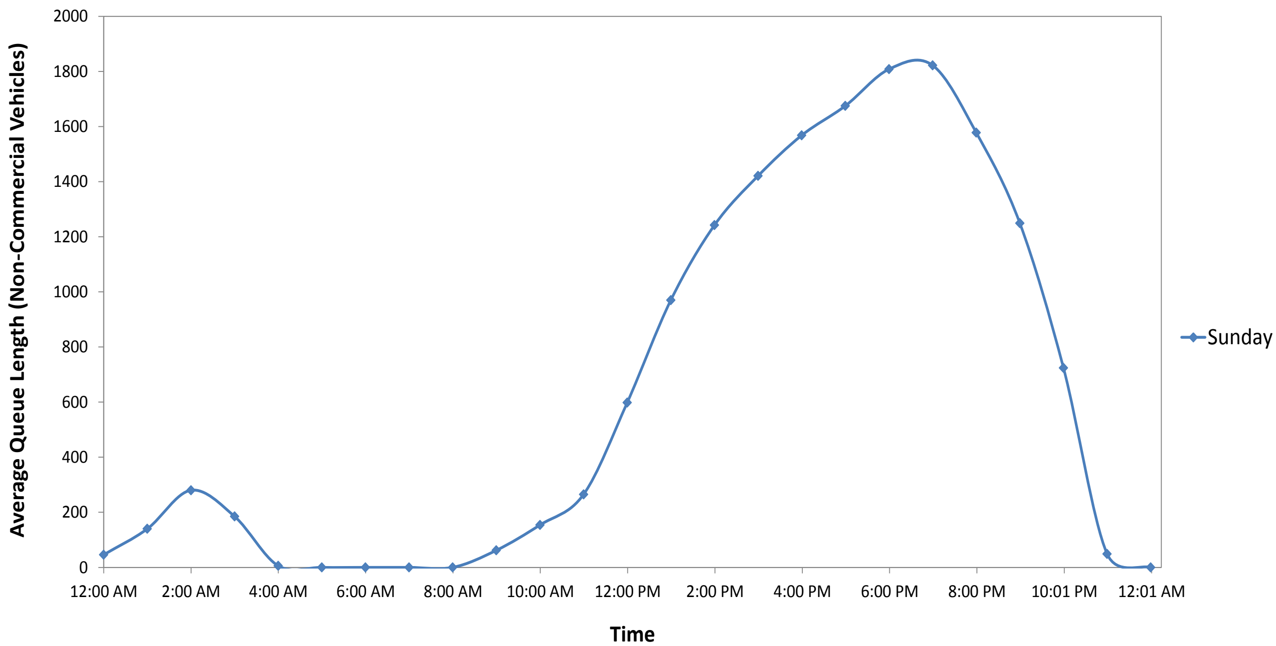

Figure 9 – Sunday Non-Commercial Vehicle Queue

Table 6 - Average Delay for Non-Commercial Vehicles on Weekday

Time	Average Delay (minutes)
12:00 AM	0
1:00 AM	0
2:00 AM	0
3:00 AM	0
4:00 AM	0
5:00 AM	0
6:00 AM	9
7:00 AM	2
8:00 AM	4
9:00 AM	21
10:00 AM	33
11:00 AM	40
12:00 PM	40
1:00 PM	51
2:00 PM	70
3:00 PM	83
4:00 PM	88
5:00 PM	104
6:00 PM	127
7:00 PM	143
8:00 PM	145
9:00 PM	128
10:00 PM	100
11:00 PM	53

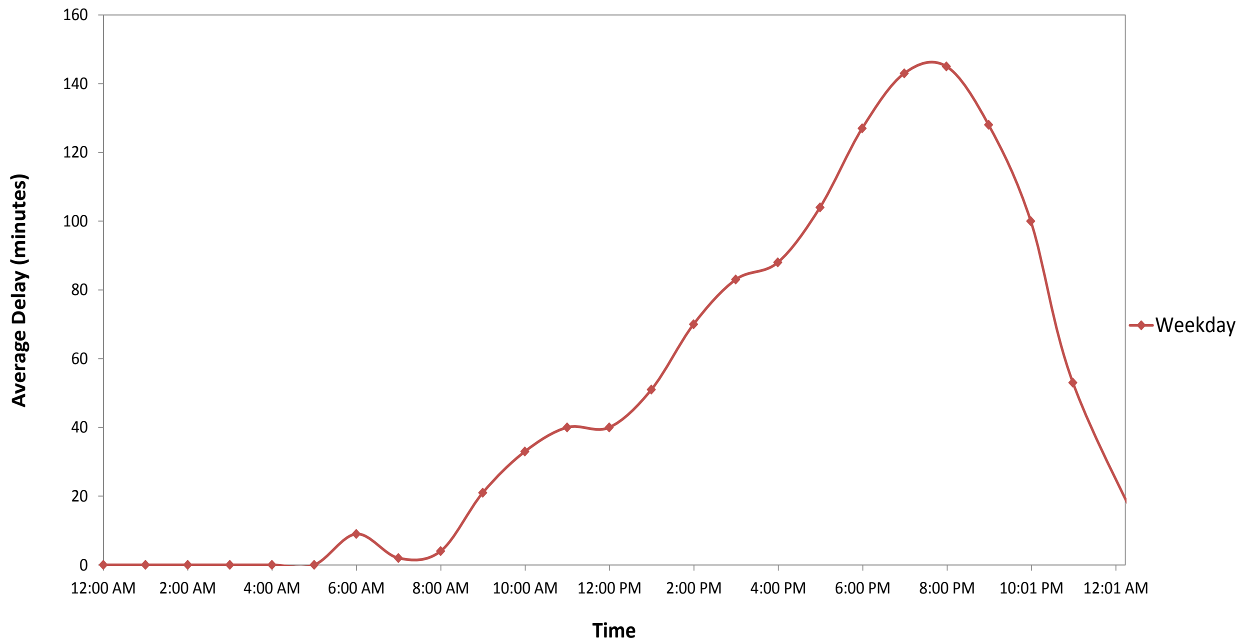

Figure 10 – Weekday Non-Commercial Vehicle Delay

Table 7 - Average Delay for Non-Commercial Vehicles on Saturday

Time	Average Delay (minutes)
12:00 AM	2
1:00 AM	8
2:00 AM	25
3:00 AM	12
4:00 AM	0
5:00 AM	1
6:00 AM	3
7:00 AM	1
8:00 AM	0
9:00 AM	2
10:00 AM	11
11:00 AM	25
12:00 PM	42
1:00 PM	54
2:00 PM	66
3:00 PM	76
4:00 PM	85
5:00 PM	98
6:00 PM	113
7:00 PM	122
8:00 PM	116
9:00 PM	97
10:00 PM	75
11:00 PM	40

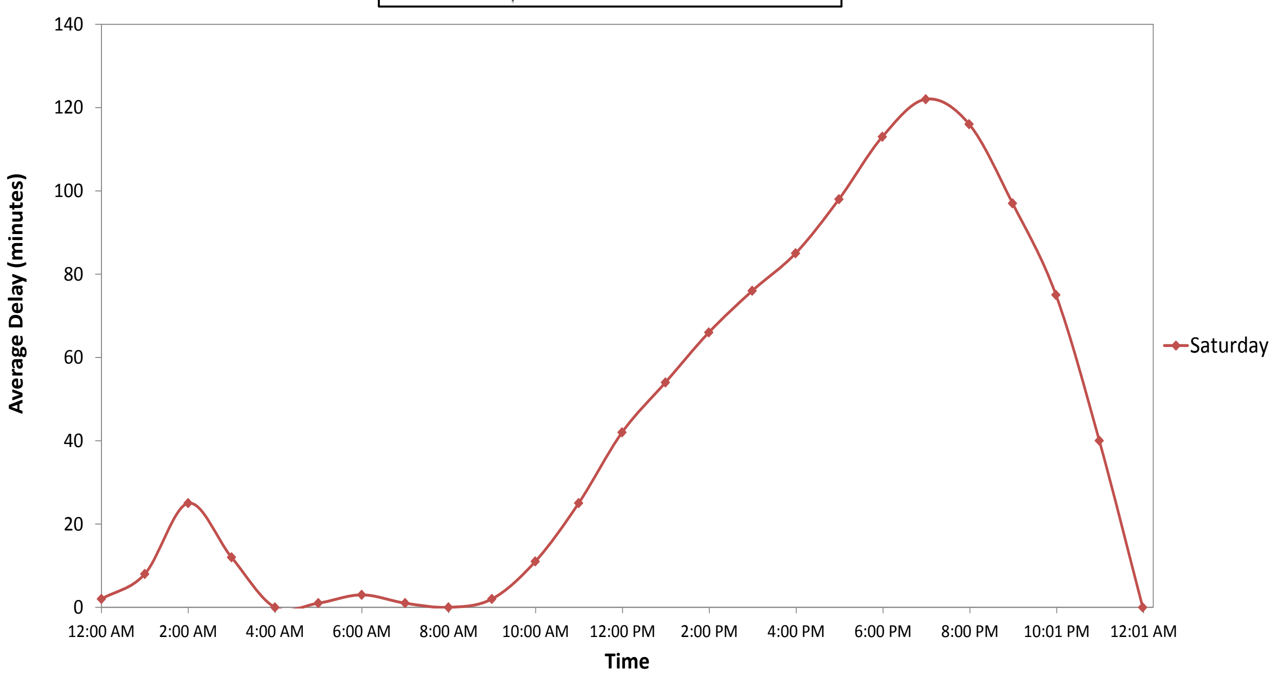

Figure 11 – Saturday Non-Commercial Vehicle Delay

Table 8 - Average Delay for Non-Commercial Vehicles on Sunday

Time	Average Delay (minutes)
12:00 AM	2
1:00 AM	8
2:00 AM	25
3:00 AM	12
4:00 AM	0
5:00 AM	1
6:00 AM	3
7:00 AM	1
8:00 AM	0
9:00 AM	2
10:00 AM	11
11:00 AM	25
12:00 PM	42
1:00 PM	54
2:00 PM	66
3:00 PM	76
4:00 PM	85
5:00 PM	98
6:00 PM	113
7:00 PM	122
8:00 PM	116
9:00 PM	97
10:00 PM	75
11:00 PM	40

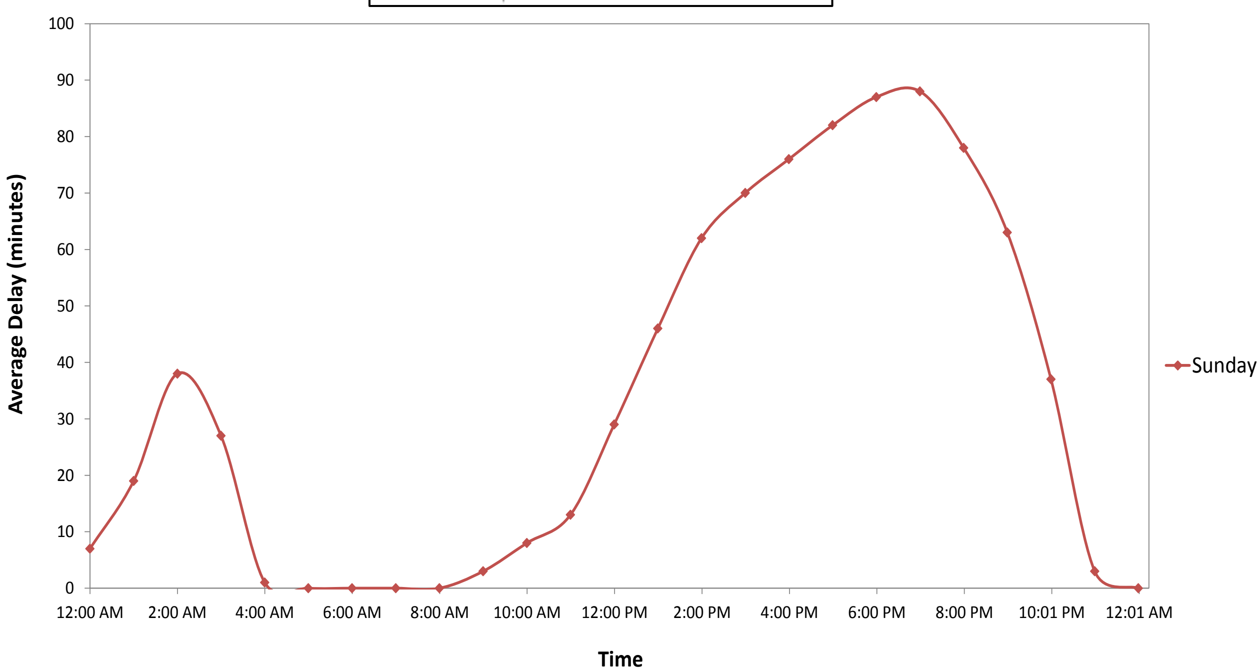

Figure 12 – Sunday Non-Commercial Vehicle Delay

C. Parameters used in Commercial Vehicles Simulation

In BQAT Analysis, a log-normal distribution for inspections times was used in the model. For service (inspection) time of commercial vehicles, the different values for average, standard deviation and maximum, as described in Table 9, were considered to be consistent with CBP reports according to MPO.

Table 9 - Discharge Times for Commercial Vehicles

Distribution	Log Normal
Mean Service Rate	80 seconds
Standard Deviation	2 seconds
Maximum Service Rate	700 seconds

Following the above values, Figure 13 demonstrates the assumed log normal distribution for the inspection time for commercial vehicles. As shown below, inspection time has a broader variability for commercial vehicles with 70 seconds as the mode.

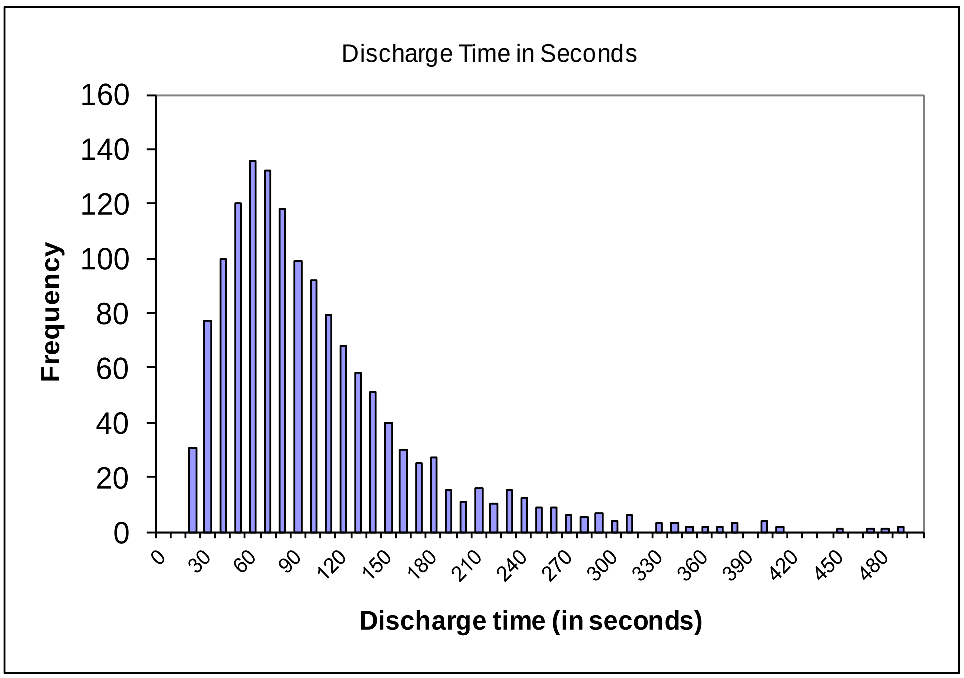

Figure 13 – Discharge Time in seconds for Commercial Vehicles

The default Poisson distribution for allocating 15-minute northbound incoming traffic into each of the one-minute intervals, also mentioned earlier, was adopted in the simulation of commercial vehicles.

Inspection booth operations followed the scheduled proposed by CBP under normal circumstances. This means that four booths are opened at 7:00 a.m. and closed at 6:00 p.m. for weekday and Saturday.

D. Queue Length and Time Delay Results for Commercial Vehicles Simulation

The following average queue and average delay were produced using BQAT when the projected volumes for June 2006 were fed into the program. Tables 10 and 11 following by Figures 14 and 15 give the queue length in vehicles for weekday and Saturday respectively.
From Figure 14, it can be seen that commercial traffic in a weekday reaches its maximum queue at noon and declines until all booths are closed in the evening. On the contrary, Saturday's queue for commercial vehicles behaves differently as can be seen from Figure 15. Here, queue lengths distinctive by having two peaks, one at 7 am and the highest at noon. The first peak observed on Saturday can be due to cargos that were late because maquiladoras could not deliver the production earlier on Friday or previous day's queue was too long.
As for delay, Tables 12 and 13 in addition to Figures 16 and 17 describes the hourly delay variations for weekday and Saturday. On a weekday, the maximum time delay occurs before 10:00 a.m. and decreases for the rest of the day until the queue dissipates. For Saturday, a curve with a maximum delay at 7:00 a.m. followed by another that occurs again at noon but with a smaller magnitude. A reason for having a longer delay in a shorter queue when compare Figures 15 and 17 is that, commercial vehicles are coming before inspection booths are open and are waiting at the gates.

Table 10 - Average Queue Length for Commercial Vehicles on Weekday

Time	Average Queue (commercial vehicles)
12:00 AM	0
1:00 AM	0
2:00 AM	0
3:00 AM	0
4:00 AM	0
5:00 AM	0
6:00 AM	9
7:00 AM	37
8:00 AM	117
9:00 AM	185
10:00 AM	275
11:00 AM	335
12:00 PM	384
1:00 PM	361
2:00 PM	273
3:00 PM	212
4:00 PM	113
5:00 PM	2
6:00 PM	5
7:00 PM	0
8:00 PM	0
9:00 PM	0
10:00 PM	0
11:00 PM	0

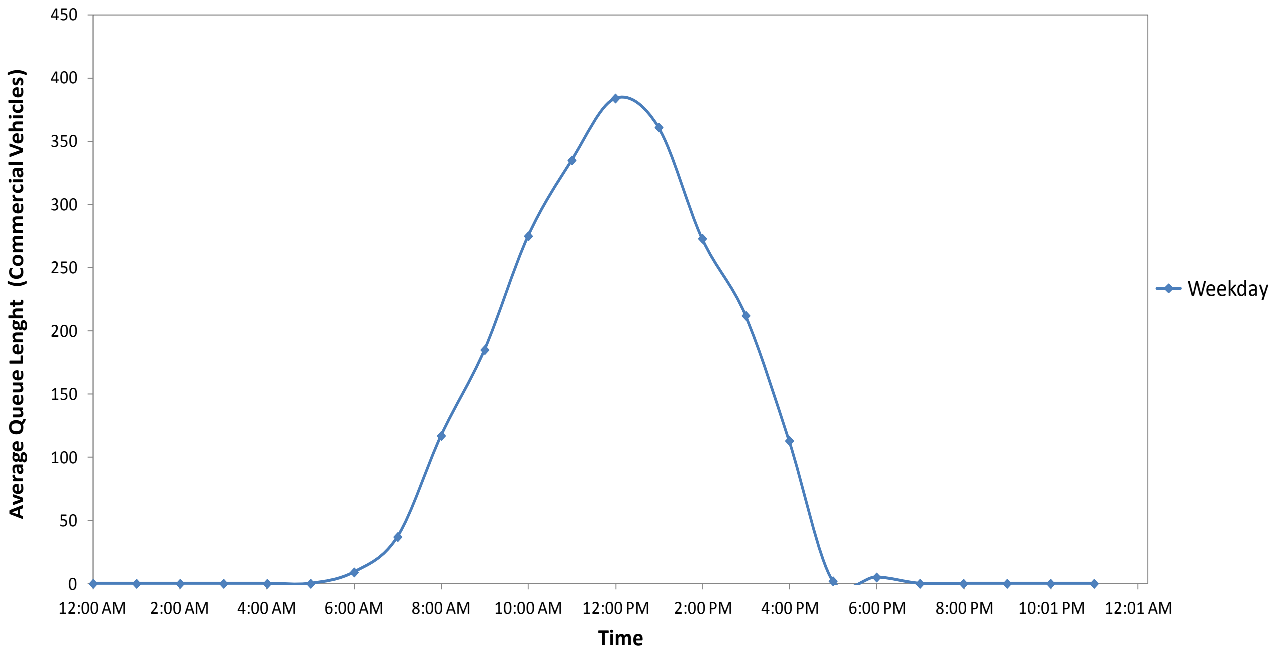

Figure 14 - Weekday Commercial Vehicle Queue

Table 11 - Average Queue Length for Commercial Vehicles on Saturday

Time	Average Queue (commercial vehicles)
12:00 AM	0
1:00 AM	0
2:00 AM	0
3:00 AM	0
4:00 AM	0
5:00 AM	0
6:00 AM	2
7:00 AM	15
8:00 AM	2
9:00 AM	1
10:00 AM	7
11:00 AM	21
12:00 PM	26
1:00 PM	0
2:00 PM	0
3:00 PM	0
4:00 PM	0
5:00 PM	0
6:00 PM	0
7:00 PM	0
8:00 PM	0
9:00 PM	0
10:00 PM	0
11:00 PM	0

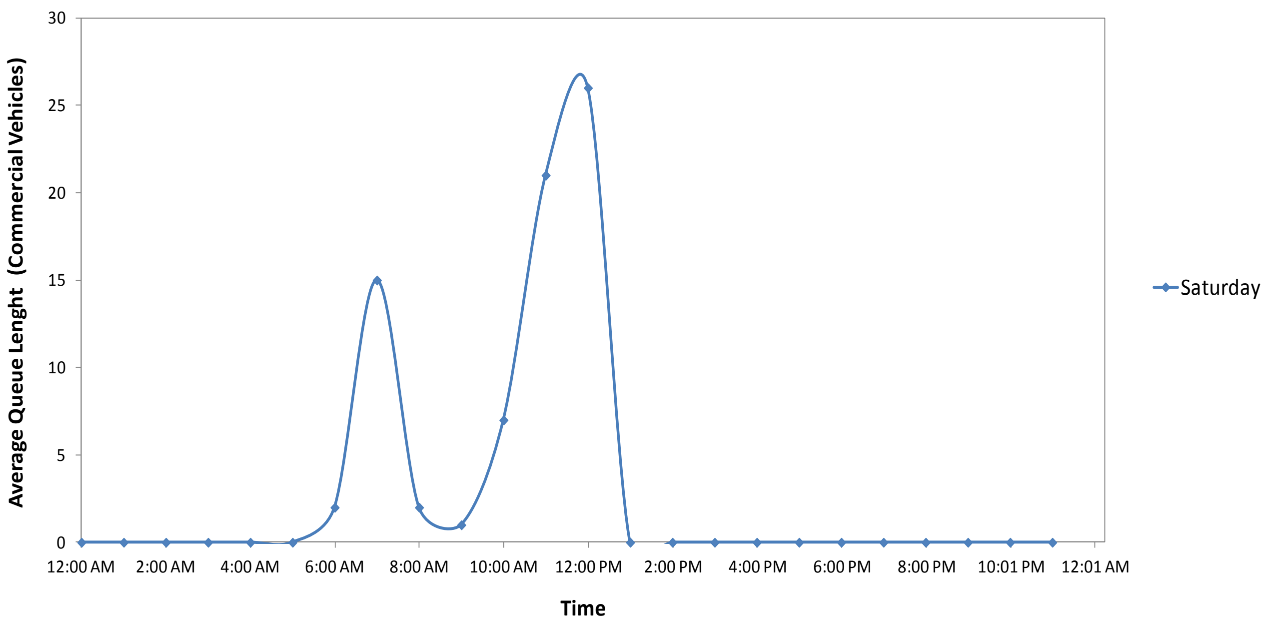

Figure 15 - Saturday Commercial Vehicle Queue

Table 12 - Average Delay for Commercial Vehicles on Weekday

Time	Average Delay (minutes)
12:00 AM	0
1:00 AM	0
2:00 AM	0
3:00 AM	0
4:00 AM	0
5:00 AM	0
6:00 AM	30
7:00 AM	29
8:00 AM	112
9:00 AM	192
10:00 AM	190
11:00 AM	166
12:00 PM	141
1:00 PM	125
2:00 PM	102
3:00 PM	68
4:00 PM	29
5:00 PM	0
6:00 PM	0
7:00 PM	0
8:00 PM	0
9:00 PM	0
10:00 PM	0
11:00 PM	0

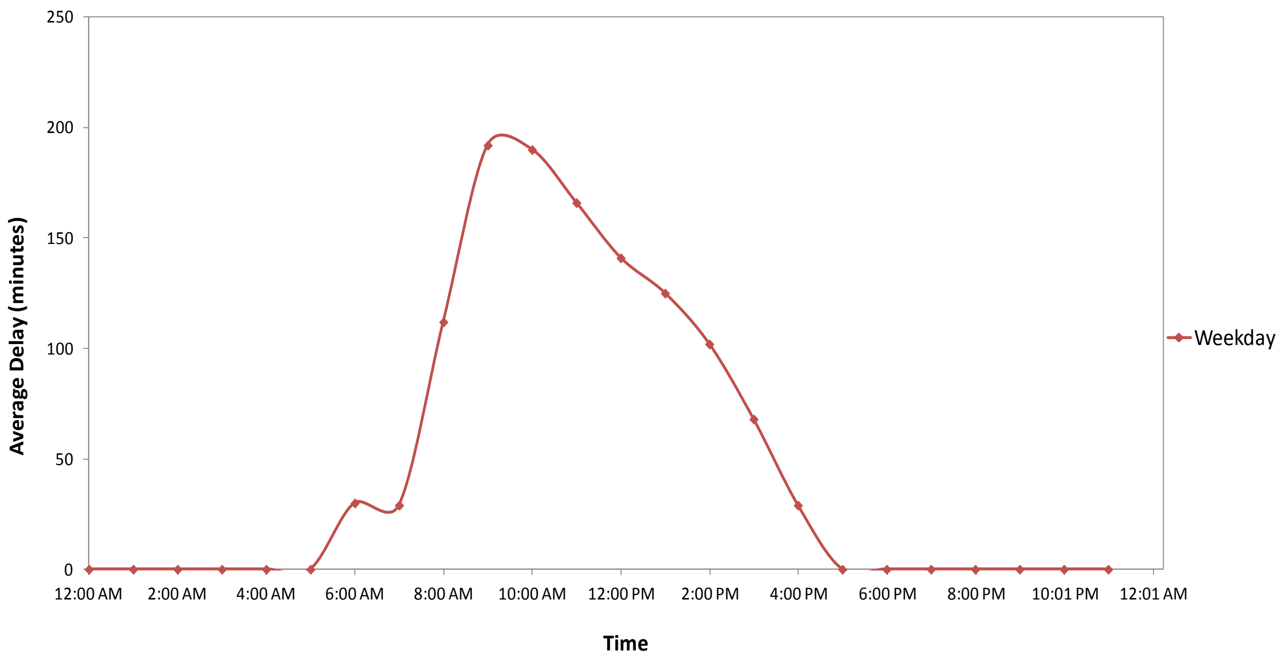

Figure 16 - Weekday Commercial Vehicle Delay

Table 13 - Average Delay for Commercial Vehicles on Saturday

Time	Average Delay (minutes)
12:00 AM	0
1:00 AM	0
2:00 AM	0
3:00 AM	0
4:00 AM	0
5:00 AM	0
6:00 AM	48
7:00 AM	35
8:00 AM	1
9:00 AM	1
10:00 AM	5
11:00 AM	16
12:00 PM	16
1:00 PM	0
2:00 PM	0
3:00 PM	0
4:00 PM	0
5:00 PM	0
6:00 PM	0
7:00 PM	0
8:00 PM	0
9:00 PM	0
10:00 PM	0
11:00 PM	0

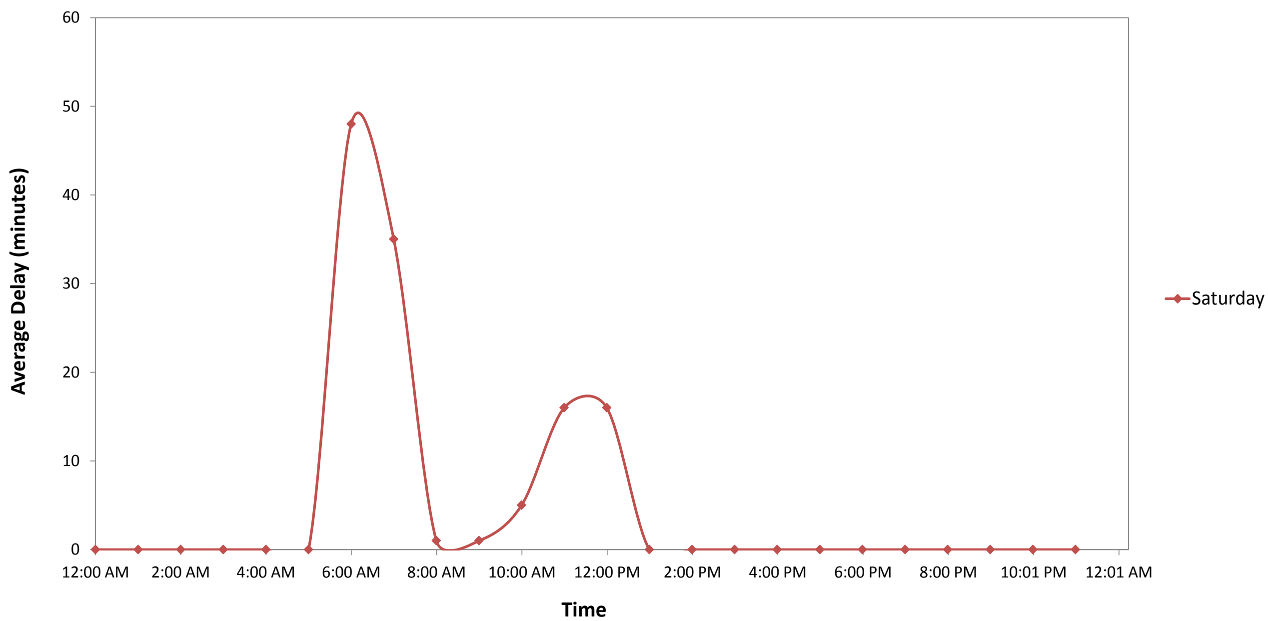

Figure 17- Saturday Commercial Vehicle Delay

REFERENCES

MPO (2006a). "Camino Real El Paso Border Improvement Plan Final Report", Wilbur Smith associates in association with Parkhill, Smith and Cooper; Huitt Zollars and Villaverde Inc., Submitted to the El Paso MPO, June 2006. Available at http://www.elpasompo.org/POE/CaminoRealBIP.pdf.

MPO (2006b) "User's Guide for BQAT", Wilbur Smith Associates, Submitted to the El Paso MPO, November 2006, accessed at http://www.elpasompo.org/POE/ElPasoBQATAnalysis.pdf.

MPO (2009). "Northbound Border Crossings: From Juarez to El Paso Summary of Bridge Crossings for 2001-2008.", El Paso Metropolitan Planning Organization, data provided by U.S. Customs Service and Border Protection. Accessed at http://www.elpasompo.org/POE/BorderCrossingYearlyTotals.pdf.