CHARACTERIZATION OF ACTIVITY PROFILES FOR CROSS-BORDER TRANSIT BUSES

FINAL REPORT

by

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August 2015
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ACKNOWLEDGMENTS

This research effort was funded jointly by TCEQ with funding from EPA. The authors thank Stephen Niemeyer, Edward Moderow, Desiree Ledet, Mary McGarry-Barber, and Daniel Perry of TCEQ for their guidance and support during the project. In addition, the following Texas A&M Transportation Institute (TTI) researchers made contributions without which this study would not have been possible: Nicholas Wood, Tara Ramani, and Boya Dai.

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EXECUTIVE SUMMARY

This project was conducted for the Texas Commission on Environmental Quality and the United States Environmental Protection Agency by the Texas A&M Transportation Institute. The research focuses on the activity of cross-border transit buses in the Paso del Norte region, which includes the cities of El Paso in the United States and Ciudad Juárez in Mexico. This region is currently facing air quality challenges, making it very important to understand the emissions contributions from various sources, including cross-border traffic. Transit buses were identified as a fairly significant source of cross-border traffic about which very limited information was currently available. Understanding the activity characteristics of these vehicles is a first step to accurately estimating their air quality impacts.

The overall goal of this research was to address the existing gap in information about cross-border bus operations by collecting data and developing specific border crossing drive cycles for these buses. Researchers conducted a review of the literature and available information on bus operations and other relevant topics prior to developing a data collection plan.

The Transborde bus service, owned and operated by Dos Naciones Inc., was identified as the main cross-border transit service provider in the Paso del Norte region. This fleet was the focus of this project. The data gathered included GPS data collected from the buses as they operated on their regular routes. The data processing and analysis of GPS data were then carried out, producing a set of northbound and southbound trips that were summarized on the basis of key trip characteristics such as speed, duration, distance, and idling time percentage. The border crossing component of these trips was then defined, and drive cycle vector plots (containing second-by-second speed information) developed for the border crossing portion. These drive cycles were compiled into a spreadsheet-based data file that serves as an accompaniment to this report.

The results from this project can form the basis for a future update of the existing border crossing emissions estimation tool developed by TTI, which currently includes only light-duty vehicles and heavy-duty trucks. The findings of this project can also be used for estimating the emissions impact of cross-border transit bus activity in the Paso del Norte region.

CHAPTER 1 – INTRODUCTION

The El Paso metropolitan area in Texas is part of the Paso del Norte airshed in a region that includes the city of Ciudad Juárez, Chihuahua, in Mexico. The El Paso metropolitan area is currently partially in nonattainment for particulate matter up to 10 micrometers in size (PM_{10}) and is designated as attainment maintenance for carbon monoxide (CO). Any future downward adjustment of the National Ambient Air Quality Standards (NAAQS) for ground-level ozone or particulate matter of 2.5 micrometers in size ($PM_{2.5}$) could push the area into nonattainment for these pollutants, as well. Therefore, air quality continues to be an important concern for this important US-Mexico border area.

Cross-border vehicle traffic is a significant component of the transportation in the Paso del Norte region. The Texas A&M Transportation Institute (TTI) research team recently completed a study jointly funded by the Center for Intelligent International Transportation Research (CIITR) and the Texas Commission on Environmental Quality (TCEQ) to develop an emission estimation tool for cross-border traffic in the El Paso–Juárez area (*1*). The tool developed in this project includes only heavy-duty diesel trucks and passenger vehicles (i.e., vehicle types that comprise the majority of the traffic at the border crossings in El Paso). A review of the available data and literature sources indicated that in addition to these two vehicle types, cross-border bus traffic between El Paso and Ciudad Juárez is sizable, with approximately 20,000 crossings occurring in 2013. The majority of these buses are diesel-powered and therefore a potentially significant source of particulate matter and other emissions. However, there is very little existing information available on the operational characteristics of the buses, which is an important factor in understanding and characterizing their emissions.

The overall goal of this project is to address the existing gap in information about cross-border bus operational data by developing specific border crossing drive cycles for these buses. Information on the operational characteristics of intercity border crossing bus operations between El Paso and Ciudad Juárez will make it possible to include this important activity in the emissions estimation process for border areas. This, in turn, will support improved air quality assessments through better characterization of cross-border vehicles' emissions, and also help in the evaluation of potential effects of transportation control strategies.

The remainder of this report is organized as follows: Chapter 2 provides a literature review and state-of-the-practice assessment. Chapter 3 summarizes the cross-border bus activity data collection process employed as part of this study, and Chapter 4 compiles the findings and conclusions.

CHAPTER 2 – STATE-OF-THE-PRACTICE AND LITERATURE REVIEW

This chapter presents the findings of a literature review covering existing information on the activity and emissions characteristics of buses engaged in cross-border travel. The review also covers existing data on border crossing buses' characteristics and operations. The review focuses on cross-border passenger activities and traffic activities, bus operations across the border, and the activity and emissions characteristics of cross-border buses in the El Paso region.

The Clean Air Act Amendment of 1990 states that any area that violates established standards (i.e., the NAAQS) for the six identified pollutants (criteria pollutants) should be classified as a "nonattainment area" (*2*). The El Paso, Texas, region is currently in moderate nonattainment for PM_{10}, and in attainment maintenance for CO (*3*). A recent proposal to lower the attainment standard for ground-level ozone could push El Paso into nonattainment for ground-level ozone, as well. (*4*) Similarly, any future lowering of the $PM_{2.5}$ standard can result in the region being designated nonattainment for this pollutant.

Recent research conducted by TTI for TCEQ and CIITR (*1*) found a significant amount of cross-border bus traffic in the El Paso region. Most of these buses are diesel-powered and release particulate matter while potentially reducing the number of cross-border passenger car trips. There is currently little information on the characteristics of these cross-border transit buses, specifically with regard to their emissions and border crossing characteristics.

CROSS-BORDER PASSENGER ACTIVITY

In 2013, over 231 million passengers crossed into the United States at one of the 110 ports of entry (POEs) (*5*) by many modes. There are currently 25 land POEs on the southern border with Mexico. Texas is home to 11 POEs with the busiest of them in terms of passenger traffic located in El Paso.[*]

Almost 24 million passengers crossed into the United States at El Paso in 2013, second only to San Ysidro in California (*5*). There are six border crossings in the Paso del Norte region. The Bridge of the Americas (BOTA) and Ysleta-Zaragoza crossings in Texas, and the Santa Teresa crossing in New Mexico handle both commercial and passenger vehicles. The Fabens-Caseta, Good Neighbor Bridge, and Paso del Norte crossings handle only passenger vehicles. An additional passenger bridge, the Tornillo-Guadalupe Bridge, which will replace the Fabens-Caseta Bridge, is nearing the end of construction (*6*).

[*] A land port of entry, as defined by the US Customs and Border Protection (CBP) is a facility that provides controlled entry into or out of the US CBP, and other federal inspection agencies are housed at POEs. Crossings and bridges are grouped into POEs. For more information, see "Texas Border Master Plans" at http://texasbmps.com/.

Despite the amount of traffic that passes through the El Paso POE, many of the Customs and Border Protection inspection booths are understaffed and, depending on the time of day, may not be open (*1*). Some lanes are available only to vehicles registered in trusted traveler programs—the FAST program for commercial vehicles, and the SENTRI program for passenger vehicles.

In the past 15 years, there has been a decrease in overall cross-border passenger activity. At southern border POEs, passenger crossings peaked in 1999 when total crossings were over 290 million. From 1999, those numbers steadily declined, reaching numbers just over 150 million in 2011. The sharp decline of border crossings between 2000 and 2002 was due to increased security and inspection at the border after September 11, 2001 (*7*). The longer trend of decreasing passenger traffic until 2011 has largely been attributed to several factors, including the increase in violence in border zones, especially in Mexico, the global economic crisis of 2008, and increases in wait times to cross the border (*8*,*9*).

More recently, from 2011 to 2013, there has been an increase in total passenger crossings at southern border POEs. The numbers in El Paso show a similar trend, peaking in 2000, decreasing through 2011, and then increasing slightly from 2011 to 2013. The recent increase in passenger border crossings is likely due in part to the global economic recovery. In El Paso in particular, efforts to increase processing speed and decrease wait times at the border have been cited as a reason for the increase in number of crossings (*10*).

Figure 1 shows the total number of passenger crossings by all modes at all southern border POEs (represented by blue bars with their value on the left axis). The red line (with values on the right axis) shows passenger crossings by all modes at El Paso.

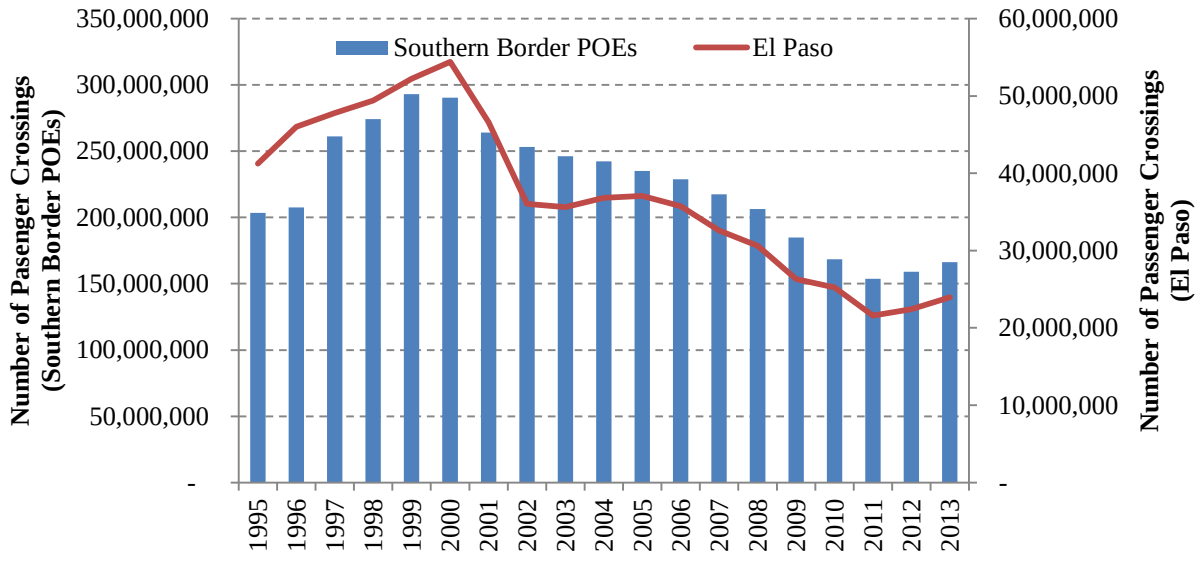

Figure 1: Total Passenger Crossings at El Paso and US Southern Border POEs.

Bus activity at the ports has followed a slightly more volatile trend than total passenger numbers. At southern border POEs between 1995 and 2003, the number of buses increased to a peak. Bus crossings in El Paso reached a peak of 32,000 crossings in 2002, showing an increase of over 20,000 buses from the previous year (*5*). The trend for El Paso has shown various increases and decreases from 2003 to 2013, loosely following the larger southern border POEs' trend. Figure 2 illustrates these trends with total number of bus crossings at all southern border POEs (represented by blue bars with their value on the left axis). The red line (with values on the right axis) shows bus crossings at El Paso. Since 2011, the number of bus crossings in El Paso has decreased slightly. The number of buses crossing at El Paso in 2013 was over 10,000 fewer than the 2002 peak.

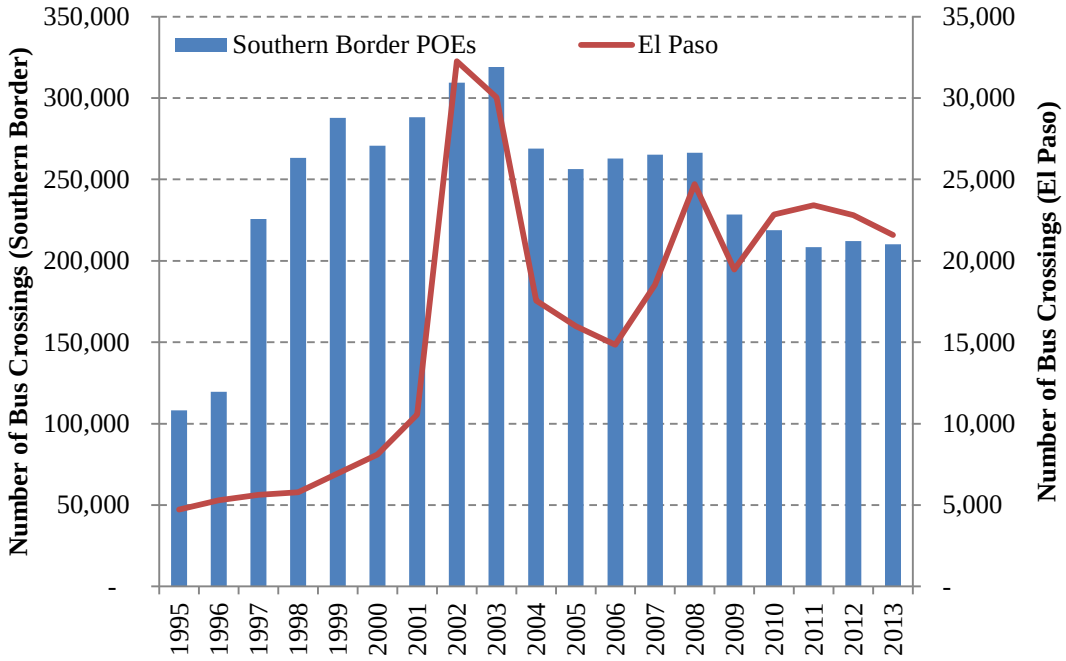

Figure 2: Number of Bus Crossings at El Paso and US Southern Border POEs.

Another aspect of relevance in understanding bus passenger travel trends is the number of passengers crossing the border by bus (as opposed to the number of buses). At El Paso, the fluctuations in number of bus passengers follow a similar pattern to the number of buses (Figure 3). For example, both bus passengers and buses increased leading up to 2002 and 2003, then decreased for three years before peaking in 2008. However, the number of bus passengers was smaller in 2002 and 2003 than in 2008, despite more buses crossing in 2002 and 2003 than 2008. These data suggest that the average bus operated was smaller in size in 2002 and 2003 than in 2008 or that buses had higher occupancy rates (i.e., closer to full capacity) in 2008.

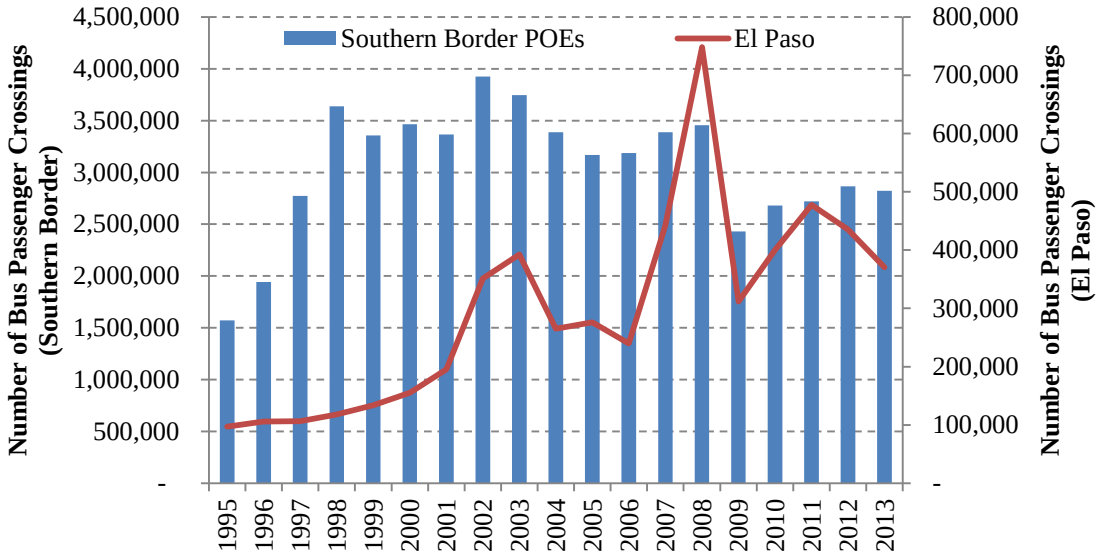

Figure 3: Bus Passenger Crossings by Bus at El Paso and US Southern Border POEs.

EXISTING STUDIES ON CROSS-BORDER TRAFFIC ACTIVITIES

This section reviews previous studies related to cross-border traffic activities, including travel time and other characteristics of cross-border passenger traffic.

Border Crossing Travel Time Study (11)

This study, conducted by RJ Rivera Associates, Inc. for the Texas Department of Transportation (TxDOT), reviewed options for improving the flow of both passengers and freight at the border. The study examined three border areas in Texas, including at El Paso.

As part of the study, the research team collected data at each of the border crossings. The data collection included daily traffic volumes, turning movement counts, travel time runs, and meetings with other stakeholders. The study then made recommendations on how to improve the congestion at the border crossings based on the data and taking into account existing constraints such as residential areas in the vicinity of the crossing.

Recommendations ranged from improving or changing specific intersections and signage for passenger vehicles and pedestrians to installing intelligent transportation systems devices to help direct traffic approaching commercial crossings.

Toward Understanding the Pedestrian Travel on the Paso del Norte Bridge (12)

This study, conducted by TTI, examined passenger traffic at the Paso del Norte International Bridge, located in El Paso, with a focus on pedestrians. The purpose of the study was to

investigate cross-border travel behavior decisions. The study examined possible causes of recent declines in the number of passengers crossing the bridge.

The study categorized motivations for cross-border travel as: tourism (including retail shopping and health services), social visits, work commutes, education commutes, and other. Influences on cross-border travel included currency movements, wait times, and safety.

Economic Impacts of Wait Times at the San Diego–Baja California Border (13)

This study, from 2006, reviewed how delay and congestion at the border crossing affected the economy. The study examined how the delay affected number of border crossings, including how that related to the purpose of the trip. The study found that the San Diego and Baja California region were economically interdependent and that 90 percent of all passenger border crossings were local in nature. Researchers also found that infrastructure was inadequate to handle increased trade and crossings and that passengers were unsatisfied with current conditions.

Developing an Emissions Estimation Tool for El Paso Border Crossings (1)[Error! Bookmark not efined.]

As part of this project, TTI developed a Microsoft Excel®-based emissions estimation tool for the El Paso border crossings. The researchers collected GPS vehicle activity data for both heavy-duty and light-duty vehicles as they crossed the border in El Paso. The GPS data, collected during different times of the day on weekdays and weekends, produced average speed data for both northbound and southbound traffic at the test location. These data, along with emissions data from the Motor Vehicle Emission Simulator (MOVES) model, allowed the research team to develop an emissions tool based on developed border crossing drive cycles.

INFORMATION ON CROSS-BORDER BUSES AND THEIR OPERATIONS

A first step to developing a data collection plan for this project was to examine available information to identify information gaps to be filled as part of the data collection process. This section summarizes the currently available information and data on buses operating at the border.

There are different types of buses that cross the US-Mexico border on a daily basis. Many are large buses that transport passengers across the border to select major cities. These buses have a capacity of greater than 50 passengers and have routes that travel from the border deep into the United States. The destinations vary depending on the border crossing location and company, but service is available to most major US cities. These routes generally follow major US roads such as Interstate or state highways once the bus has crossed the border and entered the United States.

El Paso-Juárez Bus Services

The following is a summary of the bus services operating in or through the El Paso–Juárez region.

- Greyhound (*14*)
    - Trips to Ciudad Juárez leave every two hours from El Paso daily.
    - Many long-distance trips farther into Mexico involve a transfer in Ciudad Juárez. However, there are four direct trips to other destinations daily. Destinations in Mexico include Mexico City, Monterrey, Chihuahua, Torreón, Saltillo, Guadalajara, Mazatlán, and others.
    - Buses have either 36 or 44 seats.
- Transborde
    - A Mexican company, Dos Naciones, runs this private bus service.
    - Buses cross at the Paso del Norte and Santa Fe bridges.
    - Fare is $2 and there are a number of stops in downtown El Paso and Ciudad Juárez.
    - Service is provided to the El Paso and Ciudad Juárez airports for a higher fare.
    - An additional charter service is aimed at US tourism in Ciudad Juárez, which operates one bus daily. The bus can seat 31 and costs $12.
    - The company had 12 buses as of 2013 (see Figure 4).

Transborde was founded by the mayors of El Paso and Ciudad Juárez, and is funded through an agreement between the Mexican government and the city of El Paso. The service has been running for six years, but officials reportedly do not release any information on ridership (*15*). They also do not release specific information about routes or even bus stop locations due to security concerns related to the violence in Ciudad Juárez (*16,17).* Recently, the service has been targeted at residents of El Paso as a way to promote tourism in Ciudad Juárez (*18*).

Figure 4: Transborde Bus in El Paso Region.

In an example of services in another state, Mexicoach is a company that operates tourist travel across the California border. Figure 5 shows a bus from Mexicoach, which travels a route between Tijuana and San Diego.

Figure 5: Mexican Cross-Border Bus.[†]

Passengers on buses that cross the border generally must disembark at the border for processing and permission to cross the border. This requirement can vary depending on the regulations at

[†] Image source: http://www.runoftheworld.com.

the individual port of entry, as some have a walk-on inspection process at the border (*19*). If there is a delay in processing the entry of a specific passenger, often the bus will continue on the route and the passenger will be allowed to board the next available bus that crosses the border.

Regulatory Requirements for Cross-Border Operations (*20*)

Bus operations to and from Mexico must obtain a $5 One-Trip Permit from the Texas Department of Motor Vehicles to operate into or through Texas. Buses may operate to and from specific Texas terminals of the cities listed as border commercial zones, as long as the buses are servicing the interior of Mexico. Buses may operate out of the following commercial zones in Texas:

- Del Rio
- Eagle Pass
- El Paso
- Fabens
- Laredo
- Presidio
- Brownsville
- Hidalgo
- Rio Grande City
- Progreso
- Roma

Bus Emissions Characteristics

Aside from vehicle characteristics and activity data of cross-border bus emissions, understanding the emissions and emissions rates of the buses is an important part of evaluating their emissions and assessing the effectiveness of control strategies. There is limited existing research on bus emissions in general—the focus of a majority of studies on emissions from diesel vehicles is on heavy-duty trucks. This section examines the existing research on the emissions rates of transit buses as a whole. In addition to these studies, the MOVES model is also a potential source for obtaining representative emissions rates for transit buses.

A Vehicle-Specific Power Approach to Speed- and Facility-Specific Emissions Estimates for Diesel Transit Buses (*21*)

In this study, researchers used vehicle specific power (VSP) to examine the emissions from diesel-powered transit buses. The study reviewed previously collected emissions data from buses to make a recommendation for implementing the average emissions rates of diesel-powered buses to be used in regional emissions impacts of diesel transit buses.

"On-Road Emissions Testing of 18 Tier 1 Passenger Cars and 17 Diesel-Powered Public Transport Buses" (*22*)

This US Environmental Protection Agency (EPA) study conducted emissions testing on 17 diesel-powered buses operated by the Ann Arbor Transit Authority (AATA). The project used portable emissions measurements system units to collect bus emissions data while the buses operated on their standard routes. The buses were not in normal operation during testing; they displayed an "out of service" message, but still followed the same route and made all the stops of a regular route.

"Comparing Real-World Fuel Consumption for Diesel and Hydrogen-Fueled Transit Buses and Implications for Emissions" (*23*)

This project examined key factors for emissions of both diesel and hydrogen buses, including the speed, acceleration, and road grade—all factors that make up the vehicle VSP calculations. The project used existing databases of bus emissions, including the data collected with the previously mentioned AATA (*22*), as well as data from Portuguese diesel buses. The Portuguese data included data collected at low speeds with large road grades.

"Real-World Operation Conditions and On-Road Emissions of Beijing Diesel Buses Measured by Using Portable Emissions Measurement System and Electric Low-Pressure Impactor" (*24*)

This study collected real-world emissions data from four diesel-powered buses operating in Beijing. The project collected emissions measurements for gaseous pollutants and PM. The project found that the bus emissions in real-world conditions were greater than emissions generated during engine certification cycles. Brake specification nitrogen oxide ($BSNO_x$) was 60% and 120% higher than standard limits in two Euro III emission level buses, and $BSNO_x$ was twice the limit for two Euro IV buses when measured in real-world conditions.

"Diesel and CNG Heavy-Duty Transit Bus Emissions over Multiple Driving Schedules" (*25*)

The California Air Resources Board conducted this study in which emissions data from two transit buses were collected. The project collected the data to determine the drive cycle effects on emissions, determine the differences in different heavy-duty engine technologies, and study PM emissions from the buses. Researchers collected emissions data during this project using a chassis dynamometer.

"Diesel and CNG Transit Bus Emissions Characterization by Two Chassis Dynamometer Laboratories" (*26*)

This project, conducted using West Virginia University's Transportable Heavy-Duty Emissions Testing Laboratory, examined the emissions rates from six transit buses. The buses were tested at

the Colorado Institute for Fuels and High-Altitude Engine Research and included three diesel buses and three compressed natural gas (CNG) buses. The project compared the emissions performance of the two types of buses for PM and gaseous emissions, including oxides of nitrogen (NO_x).

NO_x and PM emissions were lower in the CNG-fueled buses than in the diesel-fueled buses. Researchers also found that an aggressive driving style led to higher PM emissions while following a drive cycle representative of driving in a city's central business district.

SUMMARY

As outlined in this chapter there is not much information available on the activities of cross-border bus activity. The majority of the available information on border crossing deals with passenger and truck activity, while the information available on bus emissions is not specific to border activities. The next chapter in this report addresses the research activities the team conducted in order to collect information about the bus activities at the border. The chapter outlines the procedures used to collect the data as well as the findings from the data collection activities.

CHAPTER 3 – COLLECTING CROSS-BORDER BUS ACTIVITY

This chapter documents the process that the research team used to obtain activity information for cross-border buses operating in the El Paso–Juárez region. As mentioned in the previous chapter, there is very limited existing information on border crossing bus activities. The research team found two relevant data sources during the course of the literature review that dealt with cross-border bus activity:

- *Border Crossing/Entry Data, Bureau of Transportation Statistics (BTS) (5)* – The Research and Innovative Technology Administration publishes the most recent border crossing/entry data. These data include number of crossings by mode (e.g., bus and train passengers, private vehicles, and pedestrians). These data are available by year or month and organized by state or northern/southern border.
- *TxDOT Report: Texas-Mexico International Bridges and Border Crossings (2013) (27)* – This report provides information on the facilities and infrastructure at various Texas-Mexico border crossings.

Neither of these sources provide the fine-level data (e.g., second-by-second speed profiles and vehicle characteristics) needed for a local emissions analysis. As mentioned in the previous chapter, the Transborde bus service is the main provider of cross-border transit service between El Paso and Ciudad Juárez. Researchers obtained the necessary information regarding the buses' operations and activities in two steps: 1) obtaining general information regarding the operations and fleet through a telephone conversation with the local representatives of the company, and 2) collecting speed data through a GPS data collection effort.

General Operations and Fleet Information

The TTI research team identified a set of information and data requirements to support a local emissions estimation analysis. The Appendix lists the questions. The research team contacted the local representatives of the company Dos Naciones Inc., which operates the Transborde bus service, and the Juárez tourism and visitors center in El Paso. They gathered information via informal telephone interview, using the developed questionnaire as guidance.

GPS Data Collection

Collecting GPS activity data from a number of transit buses allowed the research team to determine a detailed characterization of the cross-border transit bus activity specifically with regard to their border crossing speed profiles. The GPS data collection follows the procedures that were developed for a research project conducted by TTI for TxDOT (*28*) and adopted for the joint CIITR and TCEQ study (*1*). A Quality Assurance Project Plan was also developed for this study, outlining the data collection and data handling procedures in further detail.

The following provides a summary of the data collection process and equipment used:

- GPS data loggers – The research team selected the QStarz BT-Q1000eX Xtreme Recorder (*29*) based on its overall performance and specifications. Figure 6 shows the QStarz BT-Q1000eX unit. The Xtreme Recorder is based on a MTK II chipset with a sensitivity of −165 dbm, which meets the desired sensitivity threshold. The unit has the capability of recording speed and position data on a second-by-second basis (1Hz) as well as 5Hz, and has a memory capacity for 64 hours of observations on the 1-Hz mode.
- Setup – Three GPS data loggers were used with each vehicle being tested. Using three data loggers instead of one allowed for protection against lost data due to a malfunctioning GPS or the unexpected loss of battery capacity in one of the units. Figure 6 shows one set of three GPS data loggers ready for testing.

Figure 6: QStarz BT-Q1000eX Unit (Left); Extended Battery Pack (Middle); and Data Loggers Prepared for Testing (Right).

- Data collection – TTI employees the GPS data while riding buses across the border carrying the GPS units. In addition to collecting speed data, having TTI employees ride the buses allowed them to better understand the process of crossing the border for the buses and the passengers. The findings are explained in the next chapter.
- Transit travel times – To gather a better understanding on the transit travel times, the trips were taken at various times of the day, including morning peak (7:00 to 9:00) and evening peak (4:00 to 7:00) hours. The total data collection lasted approximately three weeks.
- Data run procedure – Each data collection trip began with the TTI employee boarding a Transborde bus at the Transborde Terminal Station in El Paso. After boarding the bus, the employee would make the round trip across the border and back, carrying the GPS data

loggers. During the data collection the employee would stay on the bus for the duration of the round trip, other than disembarking at the border crossings. After returning to the original bus terminal in El Paso the data run would be complete.

Chapter 4 provides a summary of the findings and results from the data collection exercise, along with conclusions.

GPS Data Processing and Analysis

All the GPS data collected were processed and analyzed according to the methods developed in the joint CIITR and TCEQ study (*1*). The following provides a summary of this process:

1. Quality control and validation of raw data – Examining the speed and location data from the GPS units to determine their validity, and identifying errors and outliers in the data. Researchers filtered out the faulty information and established a database of verified unprocessed data. Multiple error detection criteria were used for this step.
2. Data processing – Merging information from the three GPS units in each assembly; extracting micro-trips; and categorizing them by the target area, road classification (highway/freeway or arterial/local), average speed bin, and type of area (urban or rural).
3. Data analysis and drive schedule development – Analyzing the processed data according to a drive schedule selection algorithm that the research team developed to identify and extract the border crossing portion of recorded trips.

Chapter 4 provides a summary of the findings and results from the data collection and analysis exercise.

CHAPTER 4 – RESULTS

This chapter covers the results from the data collection and analysis exercises documented in Chapter 3. First, a summary documentation of the information obtained through the informal interviews is presented, followed by the results of the GPS data collection and analysis.

SUMMARY OF CROSS-BORDER BUS OPERATION AND FLEET CHARACTERISTICS

Researchers conducted informal interviews with two entities to obtain additional information regarding the cross-border bus service between El Paso and Juárez. These entities were the Juárez tourism and visitors center in El Paso and Dos Naciones Inc., which operates the Transborde bus service.

Juárez Tourism and Visitors Center

The Juárez tourism and visitors center has an agreement with Dos Naciones to use the Transborde bus service for round-trip tourist-oriented service between downtown El Paso and Juárez. The passengers using this service are picked up and dropped off by Transborde buses operating on their normal daily route. Daily tours pick up passengers from the Camino Real Hotel in El Paso at 10:00 a.m., noon, 2:00 p.m., and 4:00 p.m., Monday through Saturday. A total of 20 to 30 passengers generally use this service each month. The border crossing process is the same as for all other Transborde passengers.

Dos Naciones Incorporated

Dos Naciones has been operating the Transborde bus service between El Paso and Juárez since 2007. The service is open daily, 365 days a year, and operates from 5:00 a.m. to 7:00 p.m. The Transborde service has official stations on each side of the border with some being exclusive to Transborde and others shared with the El Paso transit service provider (SunMetro).

The buses depart every 30 minutes, but the service frequency can vary depending on the demand. Most of the passengers are commuters, with many US consulate visitors and passengers who are connecting via the Juárez airport or intercity bus services offered in Juárez. The biggest delay in the travel times is when the buses cross the border. When a Transborde bus arrives at the checkpoint at the border crossing, the passengers disembark and go through the passport check, followed by customs clearance. The bus crosses with the driver through a separate inspection checkpoint. After crossing the border the passengers get back on the bus for the remainder of the trip. The delay is much longer for northbound trips (into the United States), as each passenger and their belongings are checked one at a time. If a passenger is held over for further inspection the bus may leave without them, and they are allowed to get on the next available bus.

The Transborde fleet comprises a total of 22 buses of which 18 are in service on a daily basis. All the buses are 2002 model Volvo 7900s, have diesel engines, and are equipped with 43 seats.

Each bus travels approximately 80 miles each day. Each bus is fueled at a fueling station located in Juárez approximately every three days.

GPS Data Results

The collected GPS data were processed and analyzed according to the process described in the previous chapter. The following steps were taken to extract the required information from the processed GPS data.

Trip Extraction and Route

Each round trip was identified and extracted based on the starting point and timestamps (i.e., a continuous series of second-by-second observations that started and ended at the beginning of the route in downtown El Paso). The overall route varied slightly from trip to trip as some routes ended at different stops in Juárez. However, all trips used the same border crossings when crossing the border, such as the Lerdo Bridge (Stanton Street POE) for southbound and express lanes for passenger vehicles (i.e. SENTRI lanes) on Santa Fe Bridge (Paso del Norte POE) for northbound trips.

A total of 12 southbound trips were identified. The southbound trips on the bus included a total of 10 stops, not counting the stop at the border crossing. Table 1 shows the details of each of the stops, which are shown on the map in Figure 7. Stop 10, the Juárez airport, which is located south of the Juárez bus terminal, is not shown on the map. The final destination for the southbound route varied, sometimes ending at the bus terminal and other times at the airport. In addition, the service allowed for passengers to request to be dropped off at the US Embassy, with the route changing slightly in those cases.

Table 1: Transborde Southbound Route and Stops.

Station Number	Location Name	Location
Start Point	Transborde Terminal Station	S. Santa Fe St. (El Paso)
Stop 2	Transborde Stop	Montestruc Ct. (El Paso)
Stop 3	Transborde Stop	S. El Paso St. (El Paso)
Stop 4	Transborde Stop	El Paso St./Third (El Paso)
Stop 5	Transborde Stop	Stanton/Overland (El Paso)
Stop 6	Transborde Stop	Stanton/Third (El Paso)
Stop 7	Transborde Stop	Stanton/Father Rahm (El Paso)
	Mexican Aduana Checkpoint	Stanton Street International Bridge
Stop 8	Transborde Offices	Calle Manuel Bernal 346 (Juárez)
Stop 9	Ciudad Juárez Bus Terminal	Boulevard Oscar Flores 4010 (Juárez)
Stop 10	Ciudad Juárez Airport	Carretera Panamericana km 18.5 (Juárez)

Table 2 shows a summary of the southbound drive cycles with regard to key trip characteristics (distance, duration, speed, and idling time percentage).

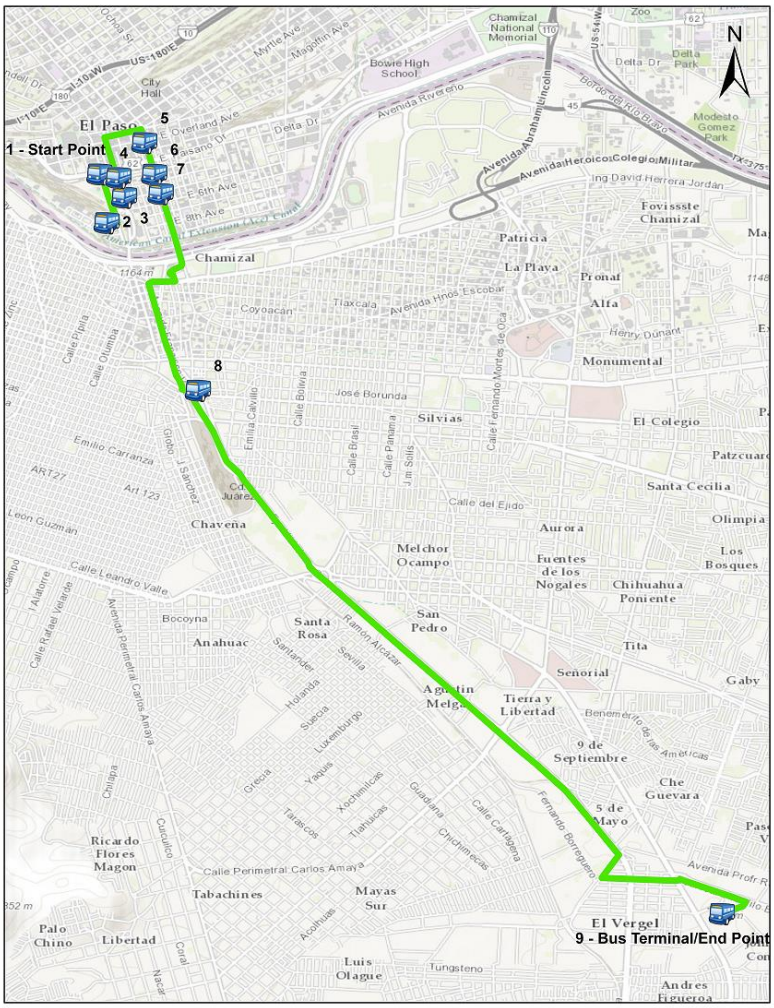

Figure 7: Transborde's Southbound Route and Stops.

Table 2: Summary of Southbound Trips.

Trip Number	Total Distance (mile)	Total Duration (minutes)	Average Speed (mph)	Idling Percentage
1	6.45	66.38	5.83	61%
2	5.87	51.50	6.84	67%
3	6.36	46.23	8.25	48%
4*	1.45	23.80	3.66	60%
5	6.66	69.30	5.77	64%
6	7.42	77.88	5.71	60%
7	7.12	61.30	6.97	56%
8	6.36	65.85	5.79	67%
9	7.08	58.68	7.24	54%
10	7.48	71.62	6.27	61%
11	7.06	54.58	7.77	54%
12	7.06	67.75	6.26	60%
Average**	**6.81**	**62.83**	**6.61**	**59%**

* Incomplete trip

** Excluding Trip 4

The focus of this study is on the border crossing section of the trips. To extract this portion of the trip, the border crossing was defined as the portion of the travel that occurred between the last stop before the border crossing and the last point after the bridge that was common to all trips. The border crossing section of the southbound travel per this definition is shown in Figure 8. This section begins at Stop 7, near the intersection of Stanton and Father Rahm streets in El Paso and ends at the intersection of Calle Rival Gullien and Calle Ing. David Herrera Jordan in Juárez. The next section provides more details on the characteristics of border crossing bus activities.

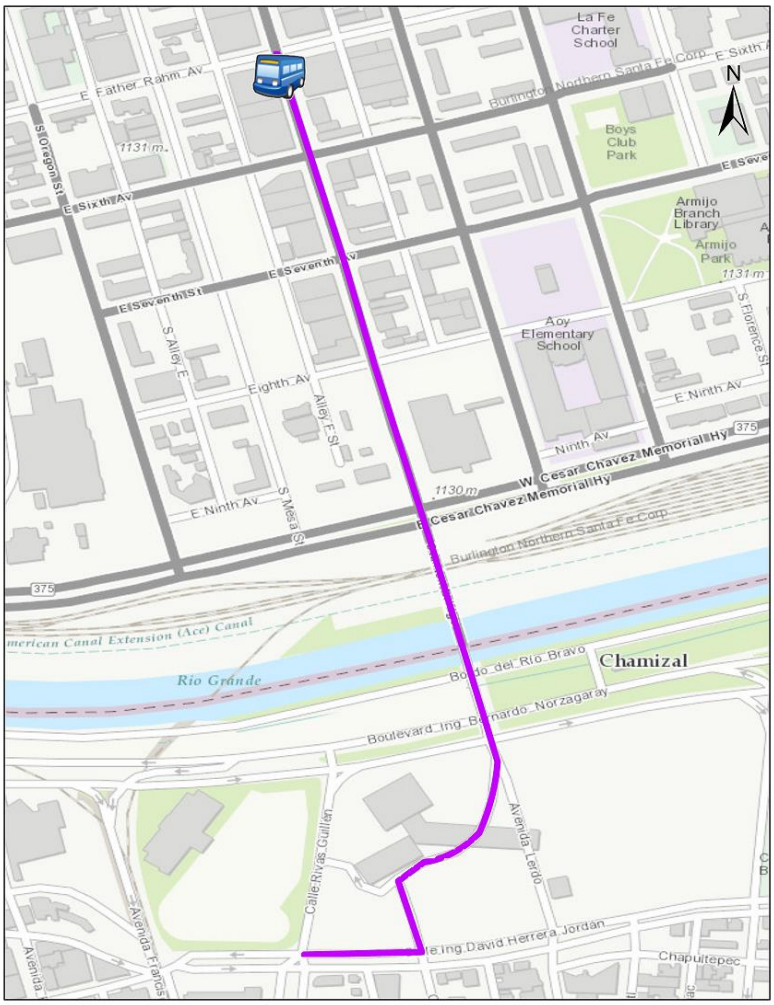

Figure 8: Southbound Border Crossing GPS Section.

The northbound trips on the bus included a total of six stops, not counting the stop at the border crossing. Table 3 shows the details of each of the stops, which are shown on the map in Figure 9. A total of 11 trips were observed for the northbound direction of travel. As with the southbound trips, the total distance and exact route taken varied slightly based on the passengers on the bus. Table 4 outlines the summary of the data collected for the northbound trips.

Table 3: Transborde Northbound Route and Stops.

Station Number	Location Name	Location
Start Point	Ciudad Juárez Airport	Carretera Panamericana Km 18.5 (Juárez)
Stop 1	Ciudad Juárez Bus Terminal	Boulevard Oscar Flores 4010 (Juárez)
Stop 2	Transborde Offices	Calle Manuel Bernal 346 (Juárez)
Stop 3	Transborde Ticket Office	Calle Gardenias 102 (Juárez)
Stop 4	US Customs and Border Protection	The Paso del Norte Bridge
Stop 5	Transborde Terminal Station	S. Santa Fe St. (El Paso)

The border crossing section of the northbound trips is between stop 3, the Transborde ticket office in Juárez and the exit of the CBP checkpoint, the intersection of East 6th Avenue and South El Paso Street, in El Paso. This section is shown in Figure 10.

Table 4: Summary of Northbound Trips.

Trip Number	Total Distance (mile)	Total Duration (minutes)	Average Speed (mph)	Idling Percentage
1	6.23	87.7	4.27	68%
2	6.24	75.17	4.98	60%
3	6.55	44.37	8.85	51%
4	6.83	104.48	3.92	71%
5	7.05	105.85	4.00	54%
6	6.53	76.42	5.12	68%
7	6.86	57.85	7.12	53%
8	7.47	80.98	5.53	54%
9	7.57	96.10	4.72	66%
10	7.51	84.65	5.33	59%
11	6.92	86.37	4.81	64%
Average	**6.89**	**81.81**	**5.33**	**61%**

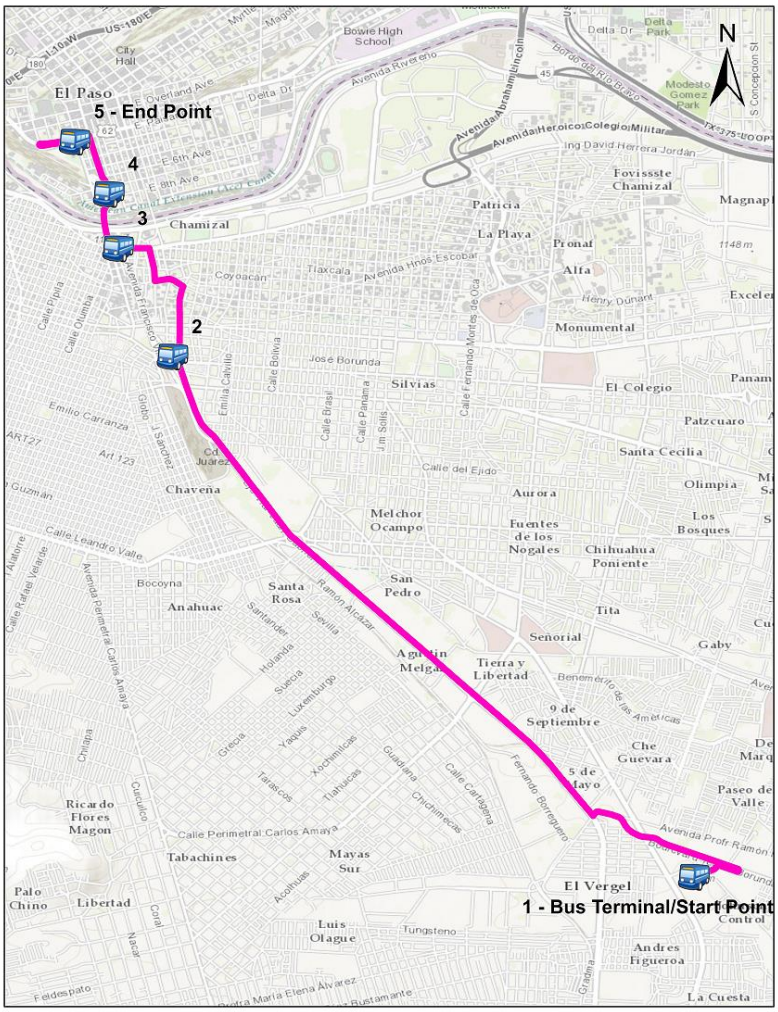

Figure 9: Northbound Trip Stops.

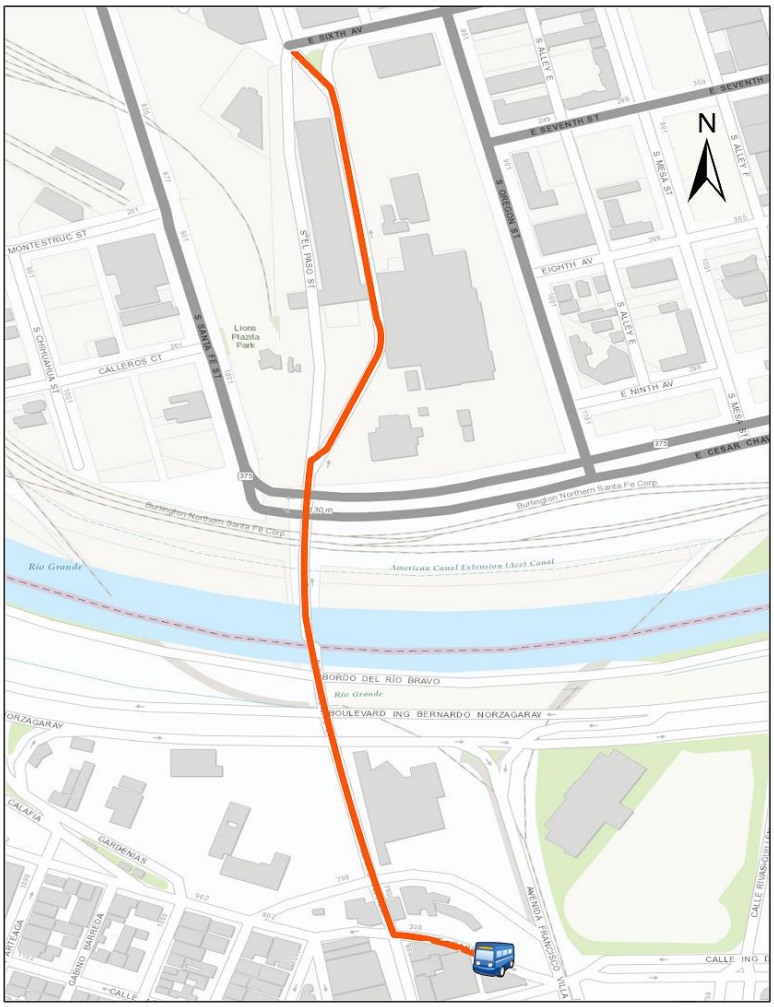

Figure 10: Northbound Border Crossing Section.

Border Crossing Activity

A total of 12 valid trips[‡] were recorded for southbound travel across the border. The processed speed information from GPS data for each trip was compiled into a second-by-second drive cycle vector and plot for the trip. A complete set of data from each of the 12 drive cycles is included in a Microsoft Excel® data file that accompanies this report.

Table 5 shows a summary of the southbound border crossing trips by the Transborde buses. The data shown in the table indicate that the buses spend the majority (79%) of the time idling while traveling in the 0.6-mile border crossing section. The average travel time for the southbound border crossing is 22.9 minutes, with a maximum of 38.4 minutes and a minimum of 13 minutes. The average speed for all southbound trips during the border crossing was 1.70 mph. Figure 11 shows a sample of one of the border crossing drive cycles.

[‡] Valid trips were those that had complete GPS data with no loss of data for the duration of the trip.

Table 5: Summary of Southbound Border Crossing Trips.

Trip Number	Total Distance (mile)	Total Duration (minutes)	Average Speed (mph)	Idling Percentage
1	0.57	23.93	1.42	79%
2	0.61	31.47	1.17	86%
3	0.60	18.53	1.93	73%
4	0.56	13.02	2.60	71%
5	0.59	28.32	1.24	85%
6	0.56	27.27	1.24	86%
7	0.55	18.00	1.83	78%
8	0.59	38.42	0.92	89%
9	0.58	13.63	2.57	68%
10	0.59	22.95	1.55	78%
11	0.62	14.58	2.56	72%
12	0.59	25.37	1.40	81%
Average	**0.58**	**22.96**	**1.70**	**79%**

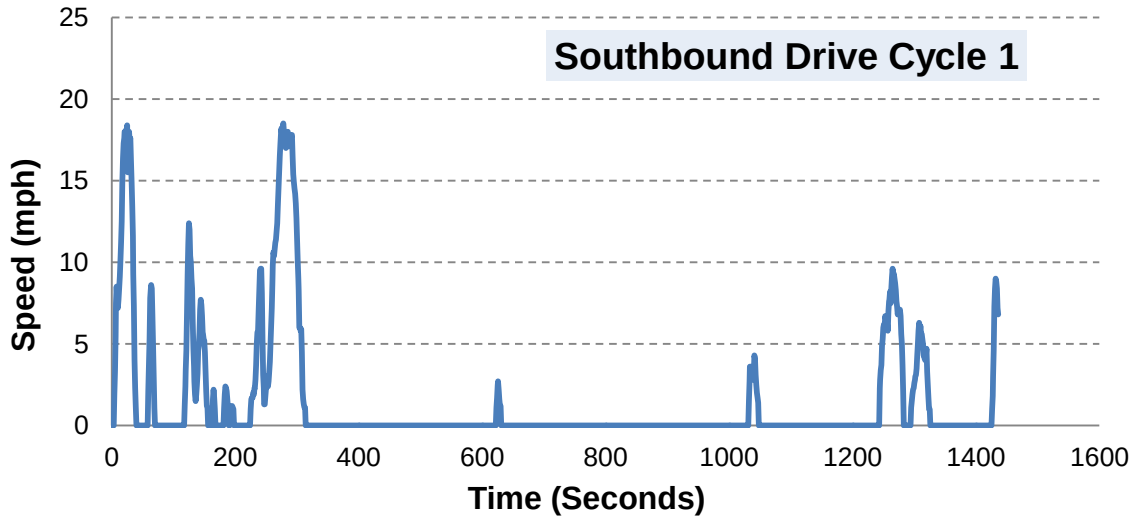

Figure 11: Sample of Southbound Border Crossing Drive Cycle.

A total of 11 valid trips[§] were recorded for northbound border crossing section of the bus activity. As with the southbound GPS data, each trip was compiled into a drive cycle vector and plot in a Microsoft Excel® file that accompanies this report.

Table 6 provides a summary of the northbound border crossing trips by the Transborde buses. The average border crossing for the northbound travel was 50.08 minutes, with the longest being 70.6 minutes and the shortest being 22.25 minutes. The buses were idling an average of 82% of

[§] Valid trips were those that had complete GPS data with no loss of data for the duration of the trip.

the time, making idling the dominant activity during the crossing. The northbound border crossings were longer than the southbound crossing due to the entry requirements and the time it took for passengers to clear customs before the bus would proceed. The total average speed during the border crossing was 0.52 mph. Figure 12 shows a sample of one of the border crossing drive cycles.

Table 6: Summary of Northbound Border Crossing Trips.

Trip Number	Total Distance (mile)	Total Duration (minutes)	Average Speed (mph)	Idling Percentage
1	0.40	62.67	0.38	85%
2	0.42	46.68	0.54	80%
3	0.40	22.25	1.08	78%
4	0.39	70.15	0.34	88%
5	0.38	70.60	0.33	83%
6	0.38	54.05	0.42	88%
7	0.41	26.82	0.92	78%
8	0.40	32.07	0.76	86%
9	0.40	63.18	0.38	90%
10	0.38	47.87	0.48	79%
11	0.39	54.50	0.43	84%
Average	**0.40**	**50.08**	**0.55**	**84%**

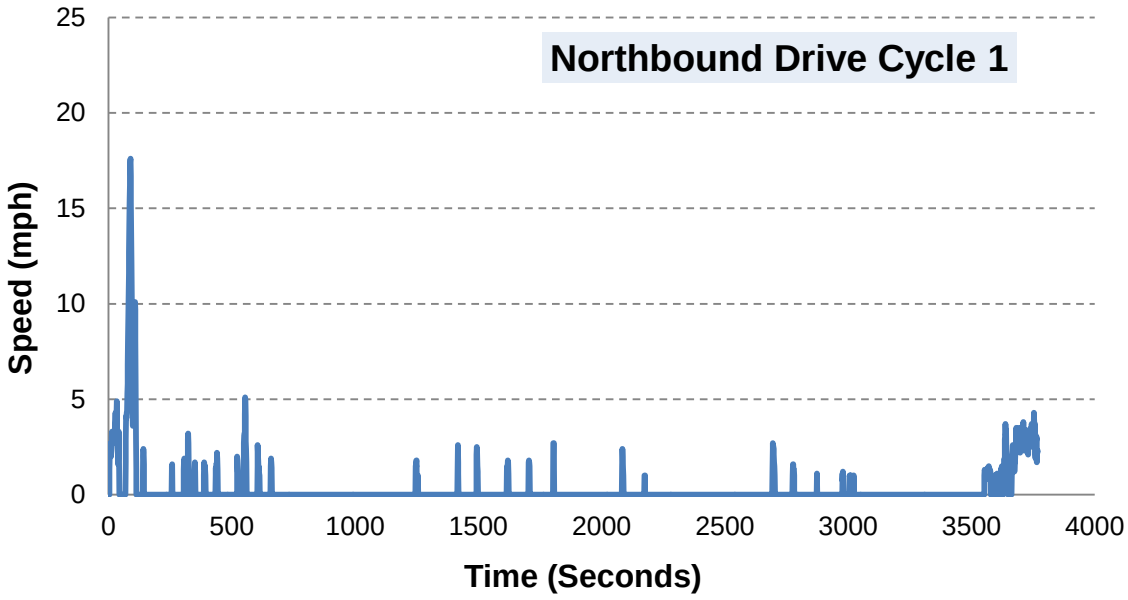

Figure 12: Sample of Northbound Border Crossing Drive Cycle

CHAPTER 5 – CONCLUSION AND FINDINGS

The overall goal of this research project was to enable the characterization of cross-border transit bus activity in the Paso del Norte region. Interviews with bus operators and a field data collection effort were performed to identify the necessary information. A set of real-world drive cycles representing the border crossing activities of cross-border transit buses in the Paso del Norte region were developed as part of this research. These drive cycles, along with information on the operational and fleet characteristics of the buses, enable the estimation of emissions impacts of these buses based on real-world data. These findings can also be used by TCEQ to incorporate the cross-border transit activity in the spreadsheet-based emission estimation tool for border crossing activities developed in a previous study (*1*).

The following are the main findings from this research:

- The Transborde bus service, owned and operated by Dos Naciones Inc., is the main cross-border transit service provider in the Paso del Norte region. Service is provided daily between locations in El Paso and Juarez.
- A review of the literature and available information on bus operations and other relevant topics was conducted prior to the development of a data collection plan. The data collection plan was then developed based on the researchers' knowledge and past experience, to fill in the gaps in available data.
- The information collected as part of the study included general fleet and operational information gathered through informal interviews, as well as GPS activity data collected onboard the buses.
- The data processing and analysis of GPS data were conducted per a three-step process, which included quality control and validation of raw data, data processing, and data analysis and drive schedule development.
- The GPS data analysis produced a set of northbound and southbound trips that were summarized on the basis of key trip characteristics such as speed, duration, distance, and idling time percentage.
- Following this, the border crossing portion of the trips were extracted, and drive cycle vector plots (containing second-by-second speed information) were developed. A Microsoft Excel®-based spreadsheet file was developed containing the resultant northbound and southbound border crossing drive cycle vectors.
- These representative drive cycles for cross-border transit bus activity were successfully developed. They can form the basis for a future update of the existing border crossing emissions estimation tool that currently includes only light-duty vehicles and heavy-duty trucks. The findings of this project can also be used for estimating the emissions impact of cross-border transit bus activity in the Paso del Norte region.

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APPENDIX – INTERVIEW QUESTIONNAIRE

INTRODUCTION

This is a project for TCEQ regarding air quality. We are trying to understand cross-border bus operations in the El Paso region and the air quality implications.

Basic Information

- Company name
- Contact person
- When the company started and how long it has been operating in El Paso
- Whether it is a public or private service

Bus Operations

- Service hours
    - Weekday vs. weekend
    - Holidays
- Passengers
    - Number of passengers served (however they are tracking this)
    - Who are they? (students, tourists, workers, etc.)
    - Difference in amount of passengers
        - Weekday vs. weekend
        - Holidays
        - Seasons
        - School in session vs. not in session
- Is this a contract service? (e.g., in the case of the Ciudad Juárez Info. Center tourist trips)
- Is there a steady distribution of trips and passengers per day?
    - Different times of day
    - Northbound vs. southbound
    - Weekday vs. weekend
- Is scheduling ever based on demand?
    - **If yes:** are trips added if there are more people/cancelled if not enough people show up?
- Is it a smooth operation (meaning getting to stops on time, crossing the border, etc.)? Or are there ever any issues that occur that affect operations?
- Idling
    - At the station or border, does the driver turn off the engine or idle?
    - Is there a rule or recommendation re. idling that the driver has to follow?

Fleet Characteristics

- Type of buses or vehicles (however they classify this)
    - Number of passengers/seats
    - Body type
    - Engine type/size/model year (if they are willing to share)
        - Diesel?
    - Do they have AC?
        - Can drivers use AC whenever they want? Or is there some sort of policy or recommendation?
- Number of buses
    - How many types of each (if applicable)
- Are all buses engaged every day?
    - Or is there a reserve of buses in case of problems?
- How many miles does each bus travel per day or month?
    - Weekday vs. weekend

Border Crossing Process

- What is the crossing process?
    - Do people get off the bus?
    - Does the bus go through an express lane?
    - How are bus drivers checked at the border?
    - Is there a difference between Northbound and Southbound process?
        - Do buses ever cross empty? Or do they wait to fill with passengers on the other side?
- What bridge do you use?
- Are there ever any issues? Delays? Non-normal conditions? (This may have already been answered at this point.)

Fueling

- Diesel or gasoline?
- Where do you fuel? (Mex vs. US, and more specific if possible)
    - **If US**: How do you choose which type of fuel to use? (Ex. cost, quality, convenience, contract, etc.)
- Does the fleet have its own fueling station?
- How often do vehicles fuel? (Daily?)
- What time of day do their fuel?
    - (Ex. before services start in the morning, when they run out of fuel, at the end of the day, etc.)