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Reducing emissions at land border crossings through queue reduction expedited security processing

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ABSTRACT

Vehicle border crossings between Mexico and the United States generate significant amounts of air pollution, which can pose health threats to personnel at the ports of entry (POEs) as well as drivers, pedestrians, and local inhabitants. Although these health risks could be substantial, there is little previous work quantifying detailed emission profiles at POEs. Using the Mariposa POE in Nogales, Arizona as a case study, light-duty and heavy-duty vehicle emissions were analyzed with the objective of identifying effective emission reduction strategies such as inspection streamlining, physical infrastructure improvements, and fuel switching. Historical traffic information as well as field data were used to establish a simulation model of vehicle movement in VISSIM. Four simulation scenarios with varied congestion levels were considered to represent real-world seasonal changes in traffic volume. Four additional simulations captured varying levels of expedited processing procedures. The VISSIM output was analyzed using the EPA's MOVES emission simulation software for conventional air pollutants. For the highest congestion scenario, which includes a 200% increase in vehicle volume, total emissions increase by around 460% for $PM_{2.5}$ and NO_x, and 540% for CO, SO_2, GHGs, and NMHC over uncongested conditions for a two-hour period. Expedited processing and queue reduction can reduce emissions in this highest congestion scenario by as much as 16% for $PM_{2.5}$, 18% for NO_x, 20% for NMHC, 7% for SO_2 and 15% for GHGs and CO. Other potential mitigation strategies examined include fleet upgrades, fuel switching, and fuel upgrades. Adoption of some or all of these changes would not only reduce emissions at the Mariposa POE, but would have air-quality benefits for nearby populations in both the US and Mexico. Fleet-level changes could have far-reaching improvements in air quality on both sides of the border.

1. Introduction

In 2014, the 25 land border crossings from Mexico into the US processed 5.4 million heavy-duty vehicles (HDVs), 2.1 billion buses, 6.96 million light-duty vehicles (LDVs) and 41.2 million pedestrians (BTS, 2015). While these land ports of entry (POE) play a vital role in enhancing the economic relation between the two countries, their traffic can present noteworthy environmental and health challenges (Olvera et al., 2013). Long queues of idling vehicles are a common sight at these ports. The emissions from idling traffic not only result in poor air quality in the vicinity of the port, but many of the vehicle emissions are also linked to adverse human health impacts (Baccarelli and et al., 2009; Ritz and et al., 2007; Salam et al., 2008;

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Peters and et al., 2004; Brugge et al., 2007; Janssen and et al., 2011; Laumbach and Kipen, 2012). For example, particulate matter less than 2.5 μm in diameter ($PM_{2.5}$) can cause respiratory issues, especially in young children and elderly individuals, leading to cardiovascular problems, as the particulates are small enough to traverse the membranes of the lungs (U.S. EPA, 2009). Further complicating the matter is the cross-jurisdictional nature of the pollution, impacting multiple states, provinces, and countries. Possibilities exist for reducing emissions through a combination of logistic improvements, technology changes, and fuel switching. Using the Mariposa POE at the Arizona-Mexico border, this study investigates the potential for emissions reductions at land ports.

The cities of Nogales, Arizona (AZ) and its Mexican counterpart Nogales, Sonora are home to three land POE's: Mariposa, Deconcini and Morley. Nogales, AZ has a population of approximately 20,000 and Nogales, Sonora has a population of nearly 213,000 (United Nations Statistics Division, 2010). With nearly a quarter of a million inhabitants in close proximity to the three POEs, accurately quantifying the drivers of air pollution and identifying reduction strategies is imperative. Another POE study at the International Bridge of the Americas between Juarez, Mexico and El Paso, Texas measured $PM_{2.5}$ and found that workers at the POE were exposed to considerably higher concentrations than the industrial occupational exposure standards (Olvera et al., 2013). The high amount of HDV traffic at the Mariposa POE could lead to similar dangerous conditions for POE workers and local communities. We focus on the Mariposa POE, which is the main entry point for fresh produce and manufactured goods from Mexico to the Western US and the busiest land port in Arizona for LDVs (U.S. General Services Administration). Currently, Mariposa POE staff process 1300 HDVs and 10,000 LDVs on average each day (BTS, 2015). The facility underwent a major infrastructural upgrade (completed in 2015) which has significantly improved the processing capabilities for both LDVs and HDVs, yet major logistical challenges remain as multiple US and Mexican agencies oversee inspection processes. Northbound HDVs have to undergo a series of inspections by several agencies including Customs and Border Protection (CBP), United States Department of Agriculture (USDA), Food and Drug Administration (FDA), Federal Motor Carrier and Safety Administration (FMCSA) and Arizona Department of Transportation (ADOT) before they are cleared to enter the US. LDVs and passenger buses from Mexico are subjected to up to two inspections by CBP before they are allowed into the US.

The objective of this study is to assess emissions from northbound vehicles at the Mariposa POE and identify potential emission reduction strategies including information technology, inspection processes, physical infrastructure improvements, vehicle technology changes, and fuel switching. Northbound vehicle movements are the primary focus of this study as the existing border crossings are not designed for commercial inspection of vehicles entering Mexico. The southbound vehicle movements, therefore, are outside the scope of this project, and likely contribute less significantly to the total POE emission profile due to the lack of a HDV queue. Historical information from the US Bureau of Transportation Statistics (BTS) as well as field data (including volume, service time and speed distributions) obtained from a two-day data collection at the port are used to establish a simulation model in the microscopic traffic simulation package VISSIM 7.0. The results from VISSIM are input to MOVES to analyze emissions.

There are no existing studies that evaluate emissions reductions at POEs with a combination of diverse logistic, technological, and fuel improvements. Furthermore, there are no studies to date that evaluate emissions specifically at the Mariposa POE, but a number of existing studies have focused on identifying bottlenecks in the vicinity of the port using traffic count, queue length and traffic delay information. Golob et al. (2008) evaluated the intersections leading into and out of the port for possible bottlenecks but did not include operations inside the port. Villalobos et al. (2010) used statistical methods like time series and multiple regression analyses to forecast traffic at the port based on historical traffic information and exogenous variables like GDP, fuel price, population etc. Villalobos et al. (2006) used simulation techniques to determine the impact of the operation of a container terminal at the Port of Guaymas on the Mariposa POE. The simulation results from the former port were used as inputs to identify bottlenecks at the Mariposa POE. The solutions proposed by these studies to mitigate congestion include (1) geometric improvements like pavement restriping, modification of turn radii, lane widening and the addition of new lanes etc. and (2) operational changes including retiming existing and installing new traffic signals.

Outside of analyses at POEs, assessment of emissions using simulation software is well developed both at macro and micro levels. Motor Vehicle Emission Simulator (MOVES) is a state-of-the-art emission modeling software developed by the US Environmental Protection Agency (EPA), and multiple studies deploy MOVES at the link-level to study specific interventions, such as light signal timing and infrastructure design (Lv and Zhang, 2012; Papson et al., 2010; Ko et al., 2012; Bernardin et al., 2012). Furthermore, MOVES has been shown to be effective at studying varying levels of vehicle congestion when linked to microscopic movement simulation (Nesamani et al., 2007; Chu et al., 2004; Huo et al., 2009), as is proposed for this project. Most recently, MOVES was used to investigate regional differences in metropolitan emission inventories due to differences in vehicle fleets and infrastructure (Reyna et al., 2015). This software is well established in the literature for performing the emission simulation necessary for this study.

1.1. Objectives

The main objectives of this study are to (i) assess vehicle movements near and within a POE with process-level detail using high fidelity vehicle trajectory information, (ii) develop a robust emissions inventory, and (iii) propose emissions reduction strategies through a variety of infrastructural, technological, and fuel change strategies. Combining VISSIM and MOVES has been shown to be an effective approach for analyzing POE emissions (FHWA, 2012). Unlike the previous studies, queued vehicle movements are not classified as stop-and-go or creeping. Instead, sample trajectories are used as inputs to