An Environmental Analysis of Vehicle Inspection and Maintenance Programs

By

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Abstract

Purpose: The purpose of this project is to find out if vehicle inspection and maintenance programs have any impact on air pollution. *Method:* This project uses interrupted time series analysis with comparison group to test the environmental impact the vehicle inspection and maintenance program has on carbon monoxide and volatile organic compounds levels. Data on carbon monoxide and VOC levels are collected for two counties. One county has implemented an inspection and maintenance program with emissions testing and the other did not. The data is gathered before and after implementation of the program to determine its environmental impact. *Results:* The analysis showed that the implementation of the vehicle inspection and maintenance program did not have a significant impact on carbon monoxide or volatile organic compound levels. *Discussion:* Overall, the research indicates that the inspection and maintenance program did not have a significant impact on the reduction of carbon monoxide and VOC. However, the drastic decrease in voc levels can be attributed to an unrelated policy change. Although the inspection and maintenance program is not exclusively linked to motor vehicle emissions, it is still a useful tool in achieving a cleaner fleet.

About the Author

Pauline Easley was born and raised in Austin, Texas. After graduating from Anderson High School in 2001, she joined the United States Navy. Pauline spent her four years in the Navy as an Information Systems Technician. At the end of her enlistment, Pauline returned to Austin, Texas to pursue a college education. Pauline obtained a Bachelor of Science in Criminal Justice from Texas State University in 2009 and has been working in Travis County courts for the past four years. In the fall of 2009, Pauline began pursuing a Master's in Public Administration to further advance her career in the public sector. Despite having a background in criminal justice, Pauline looks forward to the possibilities her research will add to the environmental sector.

If you have any questions or concerns regarding this research, please contact her at easley.pauline@gmail.com

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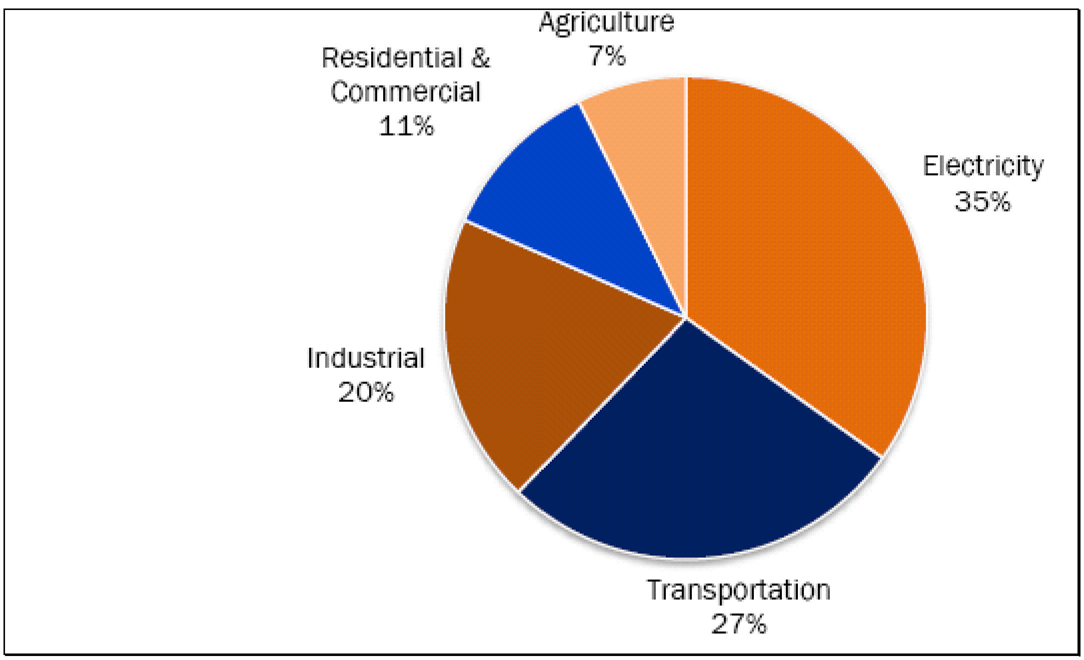
Chapter 1: Introduction

Climate change and its environmental impact are major concern not only in the United States, but around the globe. Climate change can be linked to the greenhouse effect; which is when greenhouse gases (GHG) are present in the atmosphere. These gases allow sunlight to enter the atmosphere where it warms the Earth's surface and is then radiated back into the atmosphere as heat. Greenhouse gases absorb this heat and trap it in the lower atmosphere, sparking climate change (Halmann 1998, 36). GHGs are produced by natural and human activities and can be removed from the atmosphere through natural processes. However, since the industrial revolution, human-produced GHGs have dramatically exceeded natural absorption rates. Figure 1.1 reflects the various sources of GHGs from human activity.

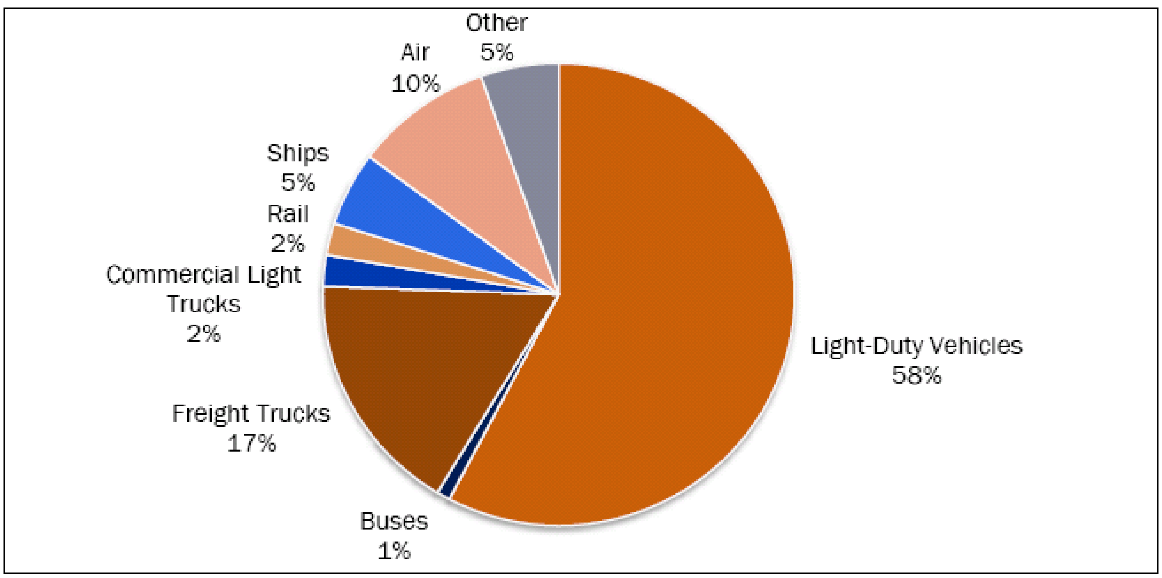
Figure 1.1: U.S. Greenhouse Gas Emissions by Sector (2008)



Source: U.S. Environmental Protection Agency (EPA), *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008*, Table ES-7, 2010. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

As the above figure shows, the transportation sector comes in second only to the power industry and is comprised of passenger vehicles, freight trucks, rails, marine and air transport. Vehicle emissions account for a large amount of carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), volatile organic compounds (VOC), and ground level ozone (smog) in the air. Ozone is formed from chemical reactions between NOx and VOC's in the presence of sunlight. Pollutants from vehicle emissions combine readily in hot, stagnant air; which in high concentrations can cause several acute and chronic illnesses (Vilet et al. 1997, 122). Of all the transportation modes, passenger vehicles, also referred to as light-duty vehicles, represent the largest percentage of greenhouse gas emitters and energy users. Figure 1.2 displays the industry percentages.

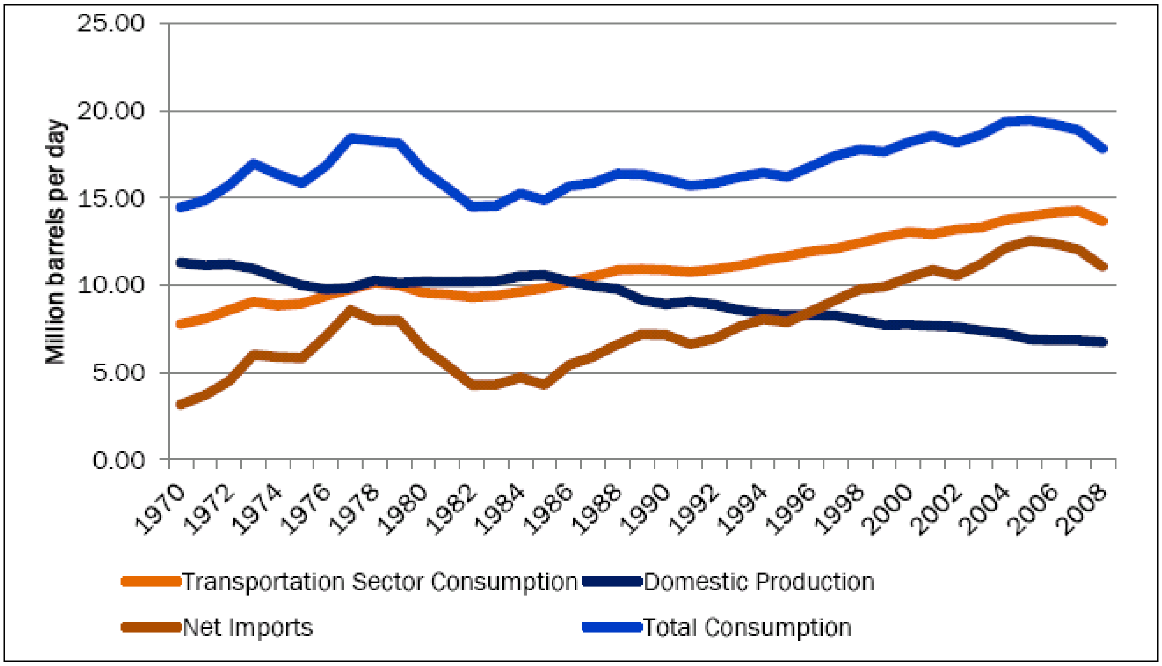
Figure 1.2 Transportation Energy Use by Mode (2008)



Source: EIA. *Annual Energy Outlook 2010*. Washington, D.C.: U.S. EIA. http://www.eia.gov/oiaf/archive/aeo10

The transportation sector is the largest consumer of petroleum based fuels in the United States; which increases foreign dependence on oil, air pollution and other global warming trends. According to the Department of Energy, dependence on foreign oil can be reduced by creating new energy sources and advances in vehicle technology (2011). Figure 1.3 reflects the trend of petroleum production and consumption levels over the past few decades.

Figure 1.3: Petroleum Production and Consumption, 1970-2008

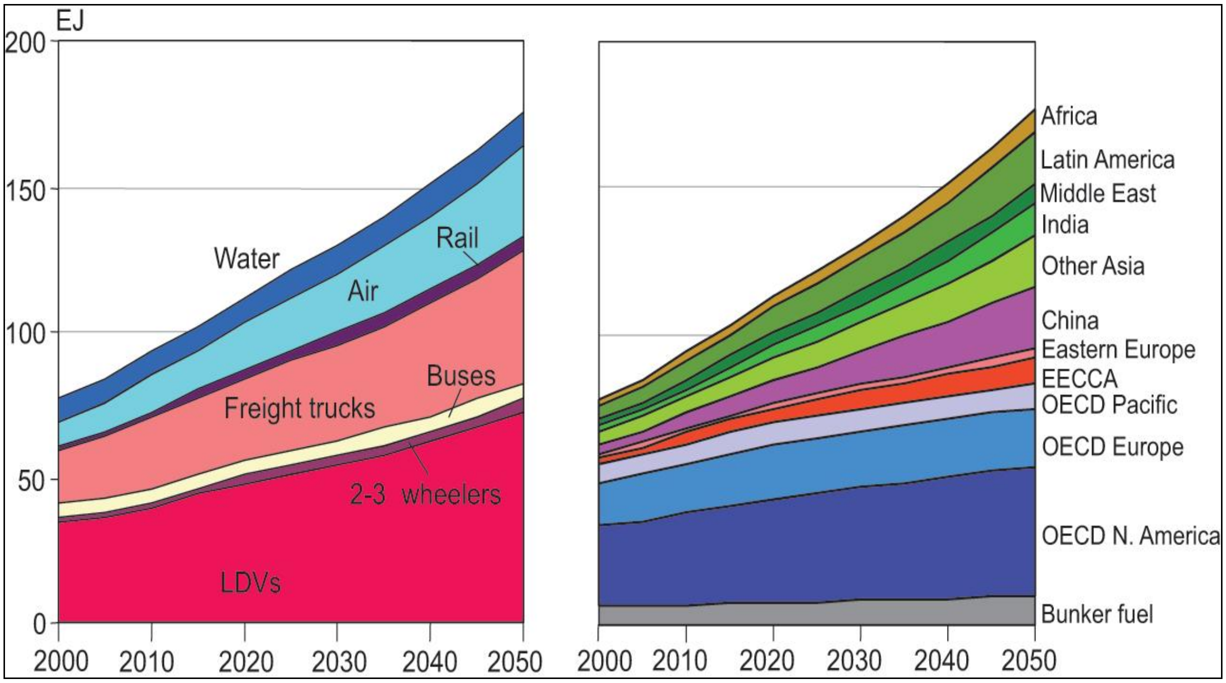


Source: U.S. Department of Energy (DOE), *Annual Energy Outlook 2010*, Table 45, 2010. http://www.eia.gov/oiaf/archive/aeo10

Transportation activity is expected to grow significantly over the next forty years in all countries and passenger vehicle ownership alone is expected to double worldwide. Most of this growth is projected to take place in countries that are still experiencing economic development. Figure 1.4 shows the expected growth of energy use by transportation mode as well as by country.

The graph shows the most growth taking place in countries that are not part of the Organization for Economic Co-Operation and Development (OECD). OECD strives for responsible economic growth and development, along with open discussions about various social and environmental policies. OECD's existence is vital in environmental policies, because many nations consider global impacts, in addition to their specific national impacts.

Figure 1. 4 Global Projections for Transportation Energy Use by mode and region, 2000-2050.



Source: Intergovernmental Panel on Climate Change (IPCC), "Transportation and its infrastructure." In Mitigation of Climate Change. Contribution of Working group III to the Fourth Assesment Report. Cambridge: Cambridge University Press, 2007. Figure 5.3 http://www.ipcc.ch/ipccreports/ar4-wg3.htm

In numerous cities across the globe, driving is the single greatest pollution activity that humans engage in. Although emissions from a single vehicle are low compared to the entire emission inventory, millions of vehicles on the road have a considerable impact on global emission levels. With the transportation sector expected to greatly increase over the next few decades, policies need to be adopted around the globe to reduce motor vehicle emissions and their impact on the environment as well as human health.

Research Purpose:

The purpose of this project is to explore the possible impact of vehicle emissions testing on air pollution. To test the impact, this project uses an interrupted time series analysis using carbon monoxide and volatile organic compounds data before and after the vehicle inspection and maintenance program was implemented in Tarrant County, Texas. To control for other intervening factors, this research uses Bexar County, Texas as a comparison county. To control for population, this research used the number of registered vehicles for each county. Fleet age for both counties is controlled by using per capita personal income.

Chapter Summaries:

Chapter two of this applied research project provides background information on emission testing development, requirements and the adoption of motor vehicle emission testing in Texas. It also explains the levels allowed for the studied pollutants; carbon monoxide and VOC. Chapter three is an in depth look at other motor vehicle emissions studies and the challenges the research faces in identifying the trends and effects of motor vehicle emissions. Chapter four operationalizes the hypotheses and explains the methodology used to collect data and test the hypotheses. An interrupted time series regression analysis is used to test the hypotheses. Chapter five presents the results of the interrupted time series analysis and explains the trends. Chapter six reviews the research project, its limitations, and makes suggestions for future studies and policies

Chapter 2: Background

Chapter Purpose:

The purpose of this chapter is to provide essential background information on emission testing development, requirements, and the adoption of the inspection and maintenance program in Texas.

Development of Emission Testing

As the west began to develop into an industrial state, pollution began to rise. Water contaminated by factory runoffs and air pollution from industrial plants pushed people away from their land in search of better environmental conditions. In 1967, groups gathered to protest the state of the environment and the damage people were causing to it. As a result, the Clean Air Act of 1970 (42 U.S.C. 7501) and its amendments was the most significant federal intervention into the environmental sector (Greenstone 2002, 1176). The Clean Air Act of 1970 required the Environmental Protection Agency (EPA) to develop federal air quality standards, establish emission standards for all motor vehicles, and develop hazardous emission standards for stationary sources. The act also gave the EPA authority to regulate fuels and fuel additives, to require automobile inspections for on-road vehicles, and to conduct assembly line testing of exhaust systems for all new vehicles. When the Clean Air Act went into effect, states were required to prepare emission reduction plans that would achieve the new federal standards within three years. Unfortunately, the law was a bit vague in establishing standards for auto emissions and granted extensions to automakers. In 1977, amendments to the Clean Air Act allowed the EPA to designate regions that did not meet the federal air quality standards as ‘non-attainment’ areas and subject them to special air quality requirements.

Emission Requirements

The EPA originally established a minimum level of air quality that all counties were required to meet for four criteria pollutants; carbon monoxide, tropospheric ozone, sulfur dioxide, and total suspended particulates. Now the EPA has six criteria pollutants to comprise the national ambient air quality standards. Carbon monoxide, ozone, and sulfur dioxide remain on the list, however, lead, nitrogen dioxide and respirable particulate matter have been added in response to conclusions from further research on air pollution. Respirable particulate matter is divided into two groups for measurement; 10 microns or less and 2.5 microns or less. If an area exceeds the allotted level for one of the criteria pollutant the area is designated non-attainment. For example, according to the EPA's National Ambient Air Quality Standards (NAAQS) carbon monoxide may not be at nor exceed 35.5 ppm during a one hour period and 9.5 ppm during an eight hour period more than once per calendar year. When a county is deemed non-attainment, it is subject to stricter regulations and government oversight than other counties, possible fines, and is given a certain amount of time to get into compliance. By falling into the non-attainment category, state and local planners are also required to include air quality goals in their transportation planning. Counties are designated attainment or non-attainment areas annually and the EPA must approve all state regulation programs to limit the degree of regulatory intensity across the states (Greenstone 2002, 1180).

Considering the transportation sector is currently second in greenhouse gas emissions, regulation had to be established to curb the growth of these very common pollutants. Motor vehicle emission standards are determined by vehicle weight class and are placed into tiers to determine standards. These tiers are then assigned pollutant levels that each vehicle in that tier must attain. For example, most passenger vehicles and light duty trucks are placed in Tier 1 and are allotted 4.4 grams per mile (g/mi) for carbon monoxide up to 50,000 miles. However, once the vehicle crosses the 50,000 mark it is allotted 6.4 g/mi for carbon monoxide. This increased allotment is due to emission equipment deteriorating as the vehicle ages (Harrington 1997, 242). Even with initial emission standards set on all new vehicles, states must still monitor emission levels for every vehicle on the road.

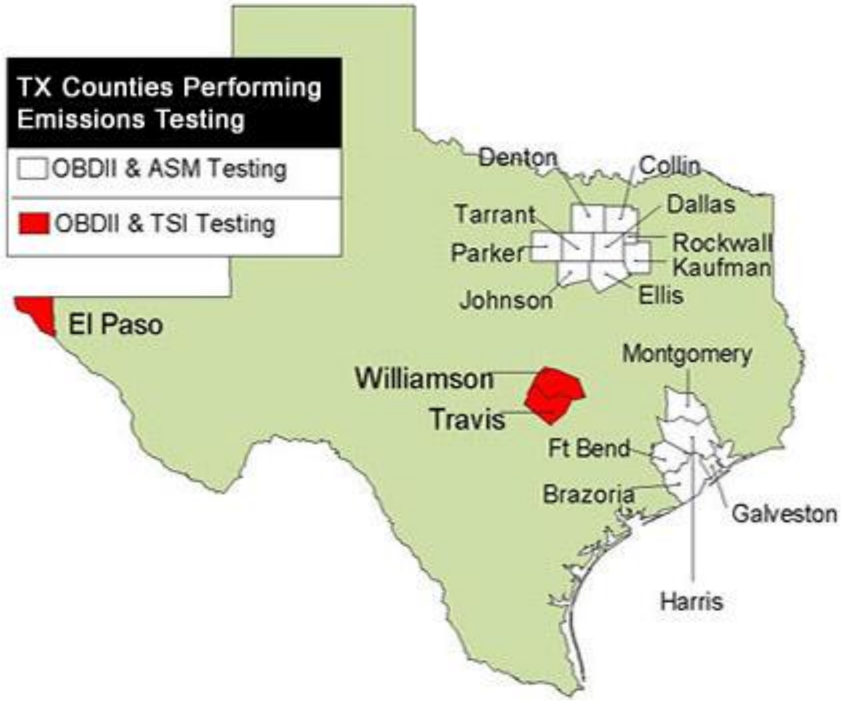
Adoption of the Inspection/Maintenance Program in Texas

Most things deteriorate with age, including motor vehicles and their emission control systems. Deterioration can cause counties to fluctuate between attainment and non-attainment designation depending upon their fleet age. Inspection and maintenance programs were first introduced in the United States in the early 1970's. The inspection and maintenance program is the simplest way to check whether the emission control system on a vehicle is working properly and to keep the vehicle in compliance of allotted emission levels.

To ensure counties are complying with EPA regulations, Texas has developed the AirCheck Texas program, which is operated by Texas Department of Public Safety and Texas Commission on Environmental Quality. The AirCheck Texas program is the vehicle inspection program, in which all vehicles registered in the state are required to receive an annual inspection. All inspections include a comprehensive safety inspection, and depending on the area, an emissions test.

Emission tests are required in counties that have been designated non-attainment by the EPA, however, some counties voluntarily implement emission testing in an effort to be proactive in environmental policy. Emission testing was implemented for Tarrant County on May 1, 2002 because they were designated non-attainment for the federal ozone standard. According to a 2008 study, only 46 percent of the ozone in Tarrant County is caused by emissions in Texas; while the rest is transported from other states and outside the United States (Schwartz 2008, 2). At the time of this research, emission testing is still required for Tarrant County. All gasoline powered vehicles, and vehicles in between the ages of two to twenty-four years old must have emission testing done yearly, if they are registered in a county that requires it. Farm machinery, road building equipment and other such vehicles are exempt from emission testing during their annual inspections, regardless of their registered county. Based on the county, there are different types of emission test performed. Figure 2.1 shows the counties in Texas and their respective emission test at the time of this research.

Figure 2.1: Texas Emission Testing Map



Source: Vehicle Inspection Program http://www.txdps.state.tx.us/vi/

All counties that require emission testing perform the On- Board Diagnostic Second Generation (OBDII) test. OBDII is a computerized system on all 1996 and newer model year vehicles that monitors emission-related equipment and systems that could affect emission levels (Pokharel et al. 2003, 5097). This system can usually detect malfunctioning components and systems before serious failures occur. The vehicle will display a malfunction indicator light when a problem arises that will cause the vehicle to exceed 1.5 times its initial emission standard.

Acceleration Simulation Mode (ASM) testing uses a dynamometer, which is a set of rollers that the vehicle's tires rest on. ASM measures carbon monoxide and volatile organic compounds under simulated driving conditions in two phases via the tailpipe. The first phase uses fifty percent of the vehicle's available horsepower at a constant

15mph. The second phase uses twenty-five percent of the vehicle's available horsepower at a constant 25mph. This tailpipe test is a cost-effective way to get very close to accurate and realistic results. A vehicle will fail the test if there is an excessive amount of volatile organic compounds, carbon monoxide or nitrogen oxide being emitted (Department of Public Safety, 2011).

Another emission test performed in Texas counties is the Two-Speed Idle test (TSI); which is a tailpipe emissions test. TSI is used for older vehicles that are not equipped with the on-board diagnostic computer system (Department of Public Safety, 2011). The analyzer measures exhaust emissions directly from the vehicle's tailpipe with the engine idling at a high speed between 2200-2800 RPM and then at a low speed between 350-1200 RPM. A vehicle will fail the test if there are excessive amounts of volatile organic compounds, carbon monoxide or carbon dioxide. Although the programs may vary state to state, the overall concept remains the same which is to have safe and clean vehicles on the road.

Chapter 3: Literature Review

Purpose

The purpose of this chapter is to review scholarly literature pertaining to motor vehicle emissions. Based on the literature, this chapter provides a definition of motor vehicle emissions and discusses the environmental and health impacts of those emissions. Next the factors and trends that affect motor vehicle emissions are discussed in order to establish their global and national importance. Finally, this chapter will address motor vehicle emission control through inspection/maintenance programs. An in depth review of the literature will highlight patterns in vehicle emission levels and corresponding policies.

What are Motor Vehicle Emissions

In order to examine motor vehicle emissions and their global impact, a clear definition of 'motor vehicle' and 'emission' should be established. Motor vehicles are gasoline or diesel fueled passenger vehicles, buses, trucks, or motorcycles that are on public roadways (Parrish 2005, 2288). For the purpose of this study, motor vehicles will also include electric powered vehicles and alternative fuel vehicles.

Motor vehicle emissions include pollutants from indirect and direct sources. There are three indirect sources of pollution. First are emissions from the production and maintenance of motor vehicle fuels. These pollutants include: butadiene, acrolein, benzene, and formaldehyde among others; which are recognized as carcinogens that can cause cancer. These pollutants are produced in the process of oil and gas extraction and petroleum refining. Second are the emissions from infrastructure, primarily road maintenance and construction. Silica and related crustal elements can often be found in suspended road dust (Murphy et al. 1999, 281). The final source of indirect pollutants are emissions from wear and tear of parts on motor vehicles. These pollutants include copper, zinc, and iron from the engine and brake wear. Platinum and rhodium from catalyst degradation also make up this category (Lipfert and Wyzga 2008, 593).

There is only one direct source of pollutants, which is emissions from the exhaust of motor vehicles. There are several pollutants found in exhaust, with the most common being nitrogen oxide, volatile organic compounds, carbon monoxide, and particulate matter. Particulate matter is only emitted from diesel powered vehicles and is vigorously monitored, but rarely included in emission studies conducted in the United States. Diesel fueled vehicles are commonly excluded because they do not consume a large percentage of the vehicle fleet in any studied area. Carbon monoxide is a colorless, odorless gas that has been the most regulated and monitored motor vehicle pollutant (Lipfert and Wyzga 2008, 592). Carbon monoxide is closely linked to vehicular traffic because it results from incomplete fuel combustion. Volatile organic compounds include hundreds of organic chemical compounds that evaporate into the atmosphere and combine with other pollutants to produce ozone. Volatile organic compounds are closely identified with motor vehicle emissions because they are produced mostly by fuel evaporations. Since carbon monoxide and volatile organic compounds are the most common pollutants monitored and linked to vehicular traffic, they define ‘motor vehicle emissions’ for the purpose of this study.

Health and Environmental Impact of Motor Vehicle Emissions

Motor vehicle emissions cause severe damage to the environment including: air pollution, loss of crops and climate change. The damage also has a trickle-down effect on human health, especially on the respiratory system.

Most motor vehicle emissions are discharged to the ambient air from exhaust systems, and are a primary contributor to air pollution, especially in urban areas. Due to the associated health risks and environmental damage, air pollution is a growing concern not only in the United States, but around the globe. As of 2002, on-road vehicles were estimated to be the single largest source for atmospheric pollutants of carbon monoxide, nitrogen oxide, volatile organic compounds, and ground level ozone known as smog. Smog is very common in heavily populated areas with heavy vehicular traffic. Automobile exhaust was first linked to the formation of smog in the early 1950's and has greatly impacted environmental policies in the United States (Bishop et al. 2008, 1651). Carbon monoxide has an atmospheric lifetime of two to three months; which plays a significant role in atmospheric chemistry, oxidizing matters and the ozone layer. Every year carbon monoxide alone contributes roughly eighty percent to the national emissions inventory (Bishop and Stedman 2007, 1651). The national emission inventory is a large database managed by the EPA. It contains emission levels collected across the United States, testing procedures, regulating information and training. High levels of air pollution can cause acid rain, which impacts the quality of life and survivability for many species.

There are devastating effects of ambient ozone on crops, even at low concentrations. Ozone enters plant leaves through stomata openings in the leaf's surface;

causing a reduction in the plant's photosynthesis process (Murphy et al. 1999, 273). Several common crops are affected by ozone including: potatoes, soybeans, tomatoes, clover, barley and even cotton. A 1999 study estimated that motor vehicle pollution causes roughly three to six billion dollars a year in agriculture damages across the globe (Murphy et al. 1999, 287). When harvest fall below expected yields the price of common crops increase dramatically, making a global impact. Unfortunately, the damaging impact of motor vehicle pollution on agriculture is not studied thoroughly, due to several other climate conditions also affecting the agriculture industry.

Climate change is the most severe and dangerous type of damage caused by motor vehicle emissions and other greenhouse gases. Climate change is unstable weather conditions and patterns, usually caused by the greenhouse effect and often missed on ordinary weather models and predictions. The most common forms of climate change are; heat waves, floods, storms, fires, and droughts (Uherek et al. 2010, 4786). Floods and storms can damage ecosystems that are not resilient against severe weather and take decades to reform, if at all. All ecosystems are intricately linked to each other, therefore when one is disturbed or destroyed, it causes a ripple effect. The literature indicates that anthropegenic temperature change is due to emissions from motor vehicles (Uherek et al. 2010, 4806). However, the relationship between climate change and motor vehicle pollution cannot be easily examined, because climate change is a gradual process and its effects are not immediately seen. The sudden changes in weather conditions increases the danger faced by all species on the planet, including human beings.

The human health system is delicate and can be affected by several environmental factors. For many decades, studies failed to link numerous chronic respiratory problems to motor vehicle emission exposure(Al Zboon 2009, 11; Lipert and Wyzga 2008, 588). However, within the past two decades scholars have been able to show a casual relationship between chronic asthma, wheezing bronchitis, shortness of breath, allergies, and chronic cough to daily exposure of motor vehicle emissions (Vliet et al. 1997, 124). Studies show that particulate matter released from diesel fueled exhausts are particularly harmful to human health. These particulate matters contain elemental carbon that creates black smoke. Also, the submicron particles from heavy-duty diesel trucks can be one hundred times larger than the emission of a catalyst- equipped, gasoline fueled automobile (Vliet et al. 1997, 130). The submicron from particulate matter is known to stick to the lungs causing lung impairment. More severe health conditions caused by motor vehicle emissions include: premature mortality, lung cancer, hypertension, heart disease, stroke and increased hospitalization (Sydbom et al. 2001, 733). Even a short exposure to vehicle emissions can spark acute symptoms of fatigue, nausea, and headaches. Vehicle occupants are most likely to experience these symptoms due to the direct exposure of pollutants.

The literature also suggests a strong relationship between chronic respiratory illnesses and the proximity of a residence to a freeway. Studies indicate the closer people live to a freeway the more emissions they will inhale for a longer period of time compared to the general population. Additionally, the more dense traffic is on the freeway, the more the residents inhale motor vehicle emissions during the day (Lipfert and Wyzga 2008, 590). Of course the strength of the pollution level from the freeway is dependent on the number of lanes and the number of freeways within any given area. The most vulnerable segment of society- children, elderly, and people with pre-existing illnesses- are more likely to develop chronic problems related to motor vehicle emission exposure than the general population.

Factors Affecting Emission Levels

There are several factors that influence motor vehicle emission levels. Distance is one of the factors that is constantly mentioned in emission studies, and is referred to as vehicle miles traveled. However, the relationship between the distance traveled and emission level for the average American driver per day has rarely been studied and documented. Annual distance traveled is increasing; for the United States alone, vehicle miles traveled have risen from about one hundred- sixty billion per year in 1990 to two hundred- sixty billion per year in 2007 (Lipfert and Wyzga 2008, 590).

Another factor influencing emission levels are driving modes and habits. There are four types of driving modes; acceleration, cruising, idle and deceleration. During the acceleration phase, the engine needs more fuel to power the vehicle, causing fuel consumption and emissions to increase. Cruise and idle modes emit the least out of the four modes, because it takes the engine less fuel to maintain the speed and engine operation. During deceleration, the flow of fuel does not stop immediately; thus an excess amount of fuel is being used, creating unnecessary emissions. This is especially true for hard deceleration changes, like continuous stop and goes during heavy traffic or city driving (Tong and Hung 2000, 551). However, most of the literature suggests that idling and low speed driving contributes a high percentage of emissions during a trip because of heavy traffic and driving conditions in urban areas, regardless of their initial low emission level (Kazopoulo et al. 2005, 1332; Bishop and Stedman 2008, 1653). Other driving habits that influence emissions are driver aggressiveness and congestion. When a driver is aggressive, it increases hard acceleration and deceleration ultimately polluting more than the driver who maintains a steady speed. Parrish (2006, 2293) mentions that during 6 a.m. and 9 a.m. more vehicles are on the road, therefore there will be more emissions during that time, than other times throughout the day.

Motor vehicle emission studies indicate vehicle characteristics are the primary influence on emission levels. These characteristics include: age, maintenance, engine load, vehicle make and model. The age of the vehicle is closely associated with the odometer reading, which indicates that the actual year of the vehicle is not the characteristic, but the mileage is (Bin 2003, 218). Naturally, older vehicles tend to be driven more, having more mileage on them. Scholars suggest that all vehicles and their emission control devices deteriorate with age. Therefore, vehicles with high mileage tend to pollute more regardless of initial emission control technologies (Faiz et al. 2006, 5968).

Maintenance is an important factor in determining how much a vehicle pollutes. Vehicles that are properly maintained and receive regular maintenance tend to pollute less, because problems are caught before parts begin to malfunction and are repaired to optimal condition. The most important maintenance is that of the engine, because it carries the load of the entire vehicle (Al Zboon 2009, 13).

Smaller engines tend to pollute much less than larger engines, because of their catalytic converter; which oxidizes majority of carbon monoxide and volatile organic compounds. The oxidation process turns emissions into a less harmful gas such as carbon dioxide, or even water. However, when vehicles stop and go, it restricts the catalytic converter from its maximum performance (Kazopoulo et al. 2005, 1333). Smaller engines also consume less fuel due to their lighter load and better gas mileage, thus polluting less over the same distance and time as larger engines. Diesel engines are the exception to pollution levels due to a large engine. Diesel engines release less carbon monoxide and volatile organic compounds than petroleum vehicles, but instead they emit more particulate matter instead.

When discussing engine load, studies discuss the importance of the air to fuel ratio. Air to fuel ratio is linked to the efficient operation of an internal combustion engine. In order for the combustion to take place, there must be a certain level of air to fuel. However, when the engine is restricted from fully reaching appropriate combustion levels the fuel is converted to carbon monoxide, volatile organic compounds and nitrogen oxide (Kazopoulo et al. 2005, 1333). The combustion process is heavily associated with driving habits and mode of driving.

Some studies suggest that imported vehicles initially pollute less than domestic vehicles (Al Zboon 2009, 12). However, domestic vehicles tend to stabilize in emission levels while imported vehicles increase in emission levels because they are driven more miles over their lifespan. One study controlled for all vehicle characteristics except vehicle make and model and did not find a significant influence on emission levels, even though vehicle make and model significance is widely suggested in the literature (Bin 2003, 220). This study suggests that since vehicles are put into tiers and given emission standards, vehicle make and model does not initially influence motor vehicle emission levels because they must meet the same standard. Based on these motor vehicle characteristics, researchers conclude that vehicles with emission violations should be identified and brought into compliance (Kazopoulo 2005, 1337; Al Zboon 2009, 12)

Several studies have shown the relationship between income and various vehicle characteristics. Researchers show that older vehicles are poorly maintained and very common in low income areas (Alberini et al. 1995, 94; Harrington 1997, 247). Any increase in the cost of new vehicles or vehicle maintenance due to emission control devices, will ultimately result in older vehicles being in use longer (Gruenspecht 1982, 329). A study by Lipfert and Wyzga (2008, 594) found that wealthier people tend to drive more miles, own newer vehicles and keep up with scheduled maintenance more than lower income individuals. Older or poorly maintained vehicles are usually termed 'gross polluters'. A study by Pokharel et al. (2003, 5097) concluded that these vehicles make up about ten to twenty percent of the entire vehicle fleet, but account for about sixty to seventy percent of all motor vehicle emissions. Higher pollution levels tend to be in areas that have lower income families and have older vehicles as a high percentage of their fleet (Kahn 1996, 194).

Fuel reformulation is vaguely mentioned in previous studies as a factor influencing emissions. In 2000, the United States reformulated fuel to remove the sulfur. By removing sulfur, vehicles run smoother and pollute less than before, ultimately reducing emissions (Harley and Coulter-Burke 2000, 4088). There are other versions of reformulated gasoline that is used in various states during certain seasons to reduce air pollutions. For example, due to the extreme heat in the summer months, Texas uses reformulated fuel that cannot exceed 1% benzene. Fuel efficiency is a common topic in motor vehicle emission studies, as well as policies. It allows vehicles to travel further on less fuel and ultimately reduce emission levels (Kahn 1996, 186; Harrington 1997, 241). The most studied impact of fuel on influencing emissions is the introduction of alternative fuels; which can significantly reduce overall air pollution (Faiz 2006, 5968; Schafer et al. 2009, 478). Compressed natural gas, bio-diesel, liquefied petroleum gas, and electric powered vehicles are among the most common types of alternative fuels mentioned in the literature (Faiz et al. 2005, 5968). Although alternative fuels still pollute, their emission levels are substantially less than petroleum based gasoline. A single compressed natural gas powered vehicle emits roughly twenty percent less carbon monoxide per mile than a petroleum gasoline powered vehicle (Uherek et al. 2010, 4794). By introducing alternative fueled vehicles into the fleet, emission levels can be significantly reduced.

The final factor influencing emissions is regulation; which sets the standards for the entire automobile industry. The Clean Air Act of 1970 was one of the earliest pieces of legislation that took a stand against air pollution. It is also the most significant federal intervention into the automobile market (Switzer 2004, 12). Among other tasks, the Environmental Protection Agency (EPA) was required to develop federal air quality standards and establish emission standards for motor vehicles. This Act also allowed the EPA to regulate in-use motor vehicle inspections for on-the-road vehicles, and to conduct assembly line testing of exhaust systems. With the implementation of this Act, California set its own emission standards that were stricter than the federal government's standards. Numerous studies have been conducted in California to determine if these standards are reducing motor vehicle emissions. These studies agree that these stricter standards do contribute to reduced emission levels (Al Zboon 2009, 12; Harley and Coulter-Burke 2000, 4092).

Federal emission standards are established by vehicle weight class and set the maximum number of grams of volatile organic compounds and carbon monoxide that can be emitted per mile of driving (Kahn 1996, 184). In 1981 the carbon monoxide standard was changed from 7.0 grams a mile to 3.4 grams a mile (Gruenspecht 1982, 329). However, as emission levels continue to rise, new standards are developed that force the auto industry to develop new emission reduction technology. As more stringent emission standards are adopted for new vehicles, there is potential for the number of old, high emission vehicles in the fleet to increase. It is unclear if tighter emission standards on new vehicles actually increase aggregate emissions in the short run, but eventually reduce them as newer vehicles replace older vehicles in the fleet (Gruenspecht 1982, 328).

Trends affecting Emissions

Population and urban development are the two most common trends affecting emission levels. Population alone is the primary trend that impacts urban development, transportation, and emissions. Between 1970 and 1990, global population increased by thirty percent and is expected to continuously increase (Price et al. 1998, 269). With an increase in population comes an increase in demand and use of transportation, fuel consumption and emissions.

In 1960, there were roughly 411 cars for every one thousand people here in the United States. That number almost doubled by 2002, resulting in roughly 812 cars per every one thousand people (Dargay et al. 2007, 18). However, this study also estimates that by the year 2030, the United States will reach its saturation level of about 852 cars per every one thousand people (Dargay et al. 2007, 15). Dargay et al. (2007, 18) mentions that China has the fastest vehicle ownership growth rate, followed by India. As population increases, vehicle ownership closely follows at a rate of ten percent a year in China alone. China's expected saturation level is 508 cars per every one thousand people. Although the saturation level is lower than the United States, China's population exceeds that of the United States. Therefore, China will ultimately have more vehicles in use than the United States, and likely with it, higher emission levels (Dargay et al. 2007, 20). There is no shortage of a global demand for more vehicles to be in use. With an increase in demand for motor vehicles, emission trends should be studied carefully, in order to determine optimum emission levels.

Between 1970 and 1987 carbon monoxide and volatile organic compound levels were constantly increasing in the United States. Eventually, those levels began to decrease or stabilize even though more vehicles were in use. Around 1992, those same pollutant levels began to rise again until 1996. With the implementation of new requirements, vehicle emission levels began to decrease and continue to decrease according to the literature (Parrish 2005, 2289; Al Zboon 2009, 14). However, the national emission levels remain high for two reasons. First, the number of miles driven per vehicle has increased dramatically as well as the number of vehicles on the road. Second, some vehicle's emission control systems began to function improperly while the vehicle was still on the road (Bin 2003, 216). Al Zboon (2009, 12) acknowledged the relationship between population and vehicle ownership and shows the growing trend of both.

As population grows, economic and urban development must assist this growth. One study in particular describes the three stages of motorized mobility development. The first stage is when an area first begins to develop, and then the need for public transportation, such as commuter rails and intercity buses, is introduced. The second stage is an increase in personal vehicles including sedans, sport utility vehicles and light duty trucks. At this stage, the need and use of public transportation usually decreases, because personal vehicle ownership and usage increases. The final stage is an increase in high speed rails and air traffic, which implies that more leisure travel is taking place (Schafer et al. 2009, 477). Of all the transportation modes, personal vehicles represent the largest percentage and the largest contributor of carbon monoxide and volatile organic compounds. Economic development increases personal vehicle ownership, mostly in part because some people may associate an increase in their personal mobility with an increase in their quality of life.

Vehicle ownership is also closely related to income per capita. Personal vehicle ownership grows relatively slow in areas with low levels of per capita personal income. At the middle income level, it grows twice as fast, then peaks during the highest levels of per capita personal income. Saturation is also reached at the highest level of per capita personal income (Dargay et al. 2007, 4). The study shows that even when per capita personal income declines, vehicle ownership does not decline, but instead the growth slows down. The literature also indicates that higher income households tend to have more vehicles per household, than lower income households. Regardless of income, studies show that vehicle ownership will continue to grow as economic development occurs (Al Zboon 2009, 12; Kahn 1996, 194)

Even though vehicle ownership increases as income, population and development grow, Marshall et al. (2004, 284) suggests population density can curb some of that growth. When population density increases so does accessibility to common areas within the community. This indicates that the more people can work, shop, eat and entertain in their own living area, the need for personal vehicles will decrease because they do not have to travel as far to reach their destinations. Also, since the vehicle ownership level decreases in dense areas, public transportation is heavily relied upon which ultimately reduces vehicle emissions. Therefore, Marshall et al. (2005, 283) recommends transportation be included in all urban planning to reduce individual passenger vehicles and emissions.

Emission Inspection and Maintenance Programs

Original inspection and maintenance programs were established in the United States in 1970. Inspection and maintenance programs were created in response to the growing speculation of discrepancies between new vehicle emission certificates and actual emissions from on-road vehicles (Harrington et al. 2000, 155). The initial program was required for non-attainment areas and was modified in 1992 to include stricter regulations. Although safety features may be tested, the purpose of inspection and maintenance programs are to identify high polluting vehicles and bring them into compliance of emission standards (Bin 2003, 216).

The literature suggests that typical inspection and maintenance programs require motorists to take their vehicle to an inspection station, where the vehicle emission control systems are monitored in different driving modes (Bin 2003, 216; Harrington et al. 2000, 154; Faiz et al. 2005, 5969). Inspection stations must be certified with the respective state and are subject to strict federal and state regulations. Due to their growing popularity, inspection and maintenance programs have been established in every state and several other countries.

Inspection and maintenance programs are usually viewed as a valuable tool to curb motor vehicle emissions, but are often criticized by what the literature identifies as several flaws. The first problem of inspection and maintenance programs is that the idle test, which is typically performed, does not mimic real life driving conditions. It does not measure acceleration or deceleration modes, which greatly affects the volatile organic compound level. Therefore, it gives a false reading of actual emission levels (Kazopoulo 2005, 1331). The second problem related to inspection and maintenance programs is that the vehicles that fail the inspection are not repaired to the point of reducing emissions, but only to pass re-inspection. Ultimately, there is no incentive for vehicle owners to purchase repairs to reduce emissions, only those that result in passing the inspection. Finally, there is a lack of consistency between states on who should monitor and administer these programs. For example, some states allow the private sector to administer tests and repairs, while other states require the public sector just to administer the test (Hubbard 1997, 54). Also, some states allow certain older vehicles to be waived or grant a waiver based on financial hardship of the owner (Hubbard 1997, 53). These inconsistencies create a nationwide gap filled by gross polluters.

Several studies question the effectiveness of inspection and maintenance programs in reducing motor vehicle emissions (Kazopoulo 2005, 1331; Harrington 2000, 157; Hubbard 1997, 54). Pokharel et al. (2003, 5100) suggests that improvements in air quality can be attributed to improvements in emission control technology in automobiles and not necessarily inspection and maintenance programs. Federal standards for new vehicles are constantly improving, which results in inspection and maintenance programs focusing on older vehicles. Unfortunately the studies fail to isolate the impact of inspection and maintenance programs on emission levels. They do not compare emission levels before implementing the program to data of emission levels after program implementation (Pokharel et al. 2003, 5100; Hubbard 1997, 54). The literature also fails to identify one effective method to measure motor vehicle emissions. Some studies use remote sensing in certain areas while other studies test a small sample at inspection stations. These studies do not give a clear report of overall motor vehicle emission levels for a given area, nor account for every vehicle in the area (Singer and Harley 1998, 3241; Harrington 1997, 243).

Conclusion

In conclusion, motor vehicle emissions are pollutants related to the use and maintenance of vehicles, from direct and indirect sources. The most commonly regulated, monitored, and studied vehicle pollutants are carbon monoxide and volatile organic compounds. The literature has identified several environmental and health hazards of motor vehicle emissions. However, the relationship between motor vehicle emissions and environmental damage and health problems seem hard to prove because of their gradualness. Several factors impact emissions including distance, driving habits and modes, vehicle characteristics, fuel, and regulation.

Global and national trends of population and economic development affect emissions in several ways which the literature identified. However, few comprehensive studies have been conducted to determine the exact effect population and vehicle ownership has on motor vehicle emission levels.

The literature addresses the purpose of inspection and maintenance programs, along with their flaws and inefficiencies. The primary discrepancy in the literature is the lack of agreement on a way to gather and measure emission levels. Rarely has any study have been conducted using official emissions level data and comparing areas to determine if inspection and maintenance programs actually work. Most studies focus on how to obtain and calculate emissions from gross polluters and other on road vehicles.

Hypotheses

The literature suggests that for the last several decades, vehicles have become more environmentally friendly than before and emit less carbon monoxide and volatile organic compounds. However, it is not clear to what extent this reduction is due to inspection and maintenance programs. In the case of Texas, few motor vehicle emission studies have been done and more counties have been deemed non-attainment over the past decade.

Conceptual Framework

The conceptual framework for this research is a formal hypothesis and is presented below in Table 3.1. This research hypothesizes that carbon monoxide and volatile organic compound levels in Tarrant County will decline once the inspection and maintenance program is implemented.

Table 3.1: Conceptual framework and supporting literature

Formal Hypotheses	Supporting Literature
H1: Counties with vehicle inspection and maintenance programs have a lower level of carbon monoxide than counties without vehicle inspection and maintenance programs. **H2:** Counties with vehicle inspection and maintenance programs have a lower level of volatile organic compounds than counties without vehicle inspection and maintenance programs.	(Alberini et al. 1995), (Al Zboon 2009), (Bin 2003), (Bishop 2008), (Cook 2007), (Dargay et al. 2007), (Faiz et al. 2006), (Greenstone 2002), (Gruenspecht 1982), (Harley and Coulter-Burke 2000), (Harrington 1997), (Harrington et al. 2000), (Hubbard 1997), (Kahill and Rasmussen 1996), (Kahn 1996), (Kazopoulo et al. 2005), (Lipfert and Wyzga 2008), (Marshall et al. 2005), (McGaughey et al. 2004), (Parrish 2006), (Price et al. 1998), (Schafer et al. 2009), (Shields and Tajalli 2006), (Singer and Harley 1998), (Switzer 2004), (Sydbom et al. 2001), (Tong and Hung 2000), (Uherek et al. 2010), (Vilet et al. 1997).

Chapter Summary

This chapter provided a clear definition of motor vehicle emissions and reviewed scholarly literature that addresses the health and environmental impacts of those emissions. Influences and trends of motor vehicle emissions were discussed, as well as inspection and maintenance programs. Finally, hypotheses were established for motor vehicle emission levels in Texas based on the literature.

Chapter 4: Methodology

Chapter Purpose:

The purpose of this chapter is to explain how the data was collected and how this project tests the hypotheses. The hypotheses are operationalized by defining how the independent and dependent variables are measured, which is discussed in the operationalization section. This chapter also explains the research design and the statistics used to determine the environmental impact of the vehicle inspection and maintenance program. The hypotheses for this study are as follows:

> **H1:** Counties with vehicle inspection and maintenance programs have a lower level of carbon monoxide than counties without vehicle inspection and maintenance programs.
>
> **H2:** Counties with vehicle inspection and maintenance programs have a lower level of volatile organic compounds than counties without inspection and maintenance programs.

Operationalization

In order to isolate the environmental impact of the inspection and maintenance program, a trend analysis of carbon monoxide and volatile organic compounds before and after the inspection and maintenance program was implemented.

The dependent variable for the first hypothesis is the fiscal year level of carbon monoxide in Tarrant County and Bexar County beginning with fiscal year 1997 through fiscal year 2002 when the program was implemented and continuing until 2007. This data was obtained from the EPA and included each active monitoring station's daily or weekly level of carbon monoxide in both counties. The data was then manually converted into fiscal years and averaged to obtain a numerical value for each respective fiscal year. A fiscal year begins October 1 of a given year and ends September 30 the following year. For example, fiscal year 1997 begins October 1, 1996 and ends September 30, 1997. This data represents the change in carbon monoxide levels in both counties before the program, which is fiscal year 1997 through fiscal year 2001 and after the program was implemented in 2002.

The dependent variable for the second hypothesis is the level of volatile organic compounds in Tarrant County and Bexar County beginning in fiscal year 1997, through fiscal year 2002 when the program was implemented and continuing until 2007. This data was obtained from the EPA and included each active monitoring station's daily or weekly level of volatile organic compounds in both counties. The data was manually converted into fiscal years and averaged to obtain a numerical value for each respective fiscal year. This data represents the change in volatile organic compound levels in both counties before the program, which is fiscal year 1997 through fiscal 2001 and after the program was implemented in 2002. Table 4.1 clearly defines each variable used in this study.

Table 4.1: Table of Operationalization

Variables	*Definition*	*Unit of Measurement*	*Data Source*
Dependent Variables			
Carbon Monoxide	A gas that forms when carbon fuel is not burned completely.	Parts per million	EPA, AQS database
Volatile Organic Compounds	Toxins that arise from fuel evaporative emissions	Parts per billion	EPA, AQS database
Independent Variables			
Per Capita Personal Income	Average income per person for each county (used as a covariant)	Personal Income in dollar amounts	Bureau of Economic Analysis, Regional Economic Information System
Registered Vehicles	Vehicles that obtained a registration sticker from the state of Texas (used as a covariant)	Total number of vehicles registered in each county	TXDOT, Communications, Analyses & Planning Department
Time (years)	A counter representing time intervals	Fiscal years	Manually created
Dummy	The level of change after the program went into effect	Codes 0 for fiscal years 1997-2001 1 for fiscal years 2002-2007	Manually created
Program	The change in growth rate for Tarrant County	Separates the data where 0 represents FY1997-2001. 1- 6 represents FY2002-07	Manually created

Table 4.1: *Continued*

Variables	***Definition***	***Unit of Measurement***	***Data Source***
Group	The difference in growth rate between the two counties disregarding the intervention time	A dummy variable where 0 represents Tarrant County and 1 represents Bexar County	Manually created
Group x Time	The difference in the two trends before the program is implemented	The product of Group variable multiplied by the variable Time	Manually created
Group x Dummy	The immediate changes between the two counties after the program was implemented	The product of Group variable multiplied by the Dummy variable	Manually created
Group x Program	The net difference in pollution levels before and after the program was implemented in Tarrant County	The product of Group variable multiplied by the Program variable	Manually created

Data Collection and Input

This project uses existing data. Data was collected beginning with fiscal year 1997 and ended with fiscal year 2007. The data for carbon monoxide and volatile organic compounds was obtained from the EPA's AQS database. Per capita personal income data was obtained from the Bureau of Economic Analysis, regional economic information system beginning with calendar year 1997 and concluding with calendar year 2007. The registered vehicle data was obtained from the Texas Department of Transportation

(TXDOT) Communications, Analysis and Planning Department. Registered vehicle data is in fiscal years. Annual per capita personal income is in calendar years. Considering income does not change substantially between calendar years and fiscal years, this will not have a significant impact on the regression analysis. There was no need to adjust the covariant of income per capita because both the program county (Tarrant) and the comparison county (Bexar) are affected similarly.

There are many monitoring stations in each of the two counties examined in this study. Each monitoring station conducts many sample testing throughout the year to measure the amount of pollutants in the air. For the purpose of this study, the average of all sample readings in a year for each county was computed. Through this method, an annual average of CO and VOC is obtained for each of the two counties that are examined in this study. The average obtained is the new value that will represent each counties carbon monoxide and volatile organic compound level for each respective fiscal year. Any sample value from the raw data that did not have a numerical value associated with it was discarded. That data represents an error in recording or monitoring for that designated time. However, if the sample produced a 0, it was kept as a valid sample.

Sample

The samples used in this study are Tarrant County and Bexar County. Tarrant County was selected to study because it is categorized as non-attainment by the EPA and has implemented an inspection and maintenance program. Bexar County was from a small pool of comparison counties for several reasons. Bexar County is one of the few larger counties that did not have an inspection and maintenance program implemented. Harris and El Paso counties were also considered for the study, but both of them have inspection and maintenance programs implemented. Tarrant and Bexar counties have service industry markets, which creates an informal environmental control. The independent variables used in this study, were also comparable between the two counties. Table 4.2 and 4.3 below gives the comparable data used in this study.

Table 4.2: Registered Vehicles

Fiscal Year	**Tarrant County**	**Bexar County**
1997	1,099,045	975,284
1998	1,159,748	1,027,704
1999	1,191,011	1,059,635
2000	1,235,916	1,094,460
2001	1,262,773	1,095,251
2002	1,316,357	1,138,183
2003	1,301,350	1,140,509
2004	1,326,899	1,170,227
2005	1,344,777	1,205,872
2006	1,411,467	1,271,316
2007	1,491,610	1,304,860

Source: http://www.txdot.gov/txdot_library/publications/stats.htm

Table 4.3: Per Capita Personal Income

Fiscal Year	Tarrant County	Bexar County
1997	25,726	22,454
1998	27,509	23,776
1999	28,504	24,963
2000	30,545	27,406
2001	31,692	27,741
2002	31,454	27,676
2003	31,902	28,546
2004	33,424	29,721
2005	35,467	31,597
2006	37,478	33,353
2007	38,834	34,972

Source: http://www.bea.gov/newsreleases/regional/lapi/lapi_newsrelease.htm

Design

This research attempts to identify the environmental impact the vehicle inspection and maintenance program has on Tarrant County, by evaluating the trends of carbon monoxide and volatile organic compounds before and after the program was implemented. This project uses an interrupted time-series with comparison group design. Table 4.2 displays the structure of the research design. In the design "X" represents intervention of the vehicle inspection and maintenance program (I/M) in Tarrant County. In the design "O" is the annual observation of carbon monoxide and volatile organic compounds. For this project, there are 5 fiscal years of observation before the program and 6 fiscal years of observation after the inspection and maintenance program was implemented in Tarrant County. The observation period for this study begins with fiscal year 1997 and continues through fiscal year 2007. The vehicle inspection and maintenance program was implemented in fiscal year 2002.

Table 4.4: Interrupted Time-Series Design with Comparison

	Before I/M program	Intervention	After I/M program
Tarrant County	O_{1997}…….O_{2001}	X	O_{2002}……O_{2007}
Bexar County	O_{1997}…….O_{2001}		O_{2002}……O_{2007}

Design Strengths

This is a classic quasi-experimental design with a comparison group. It is reliable because it allows data to be collected and analyzed at various points before and after the program was implemented. All data was collected 5 years before and 6 years after the implementation of the inspection and maintenance program in 2002. By using a comparison group, many threats to validity can be eliminated because both counties are subject to the same state policies and regulations, along with environmental trends. Inclusion of registered vehicles as covariant strengthens this research by controlling for differences in population, considering that both counties experienced roughly the same amount of vehicular growth every year observed.

This research also uses personal income per capita as a covariant. Personal income per capita is used as a surrogate to control for fleet age. Previous review of the literature suggested wealthier people tend to own newer vehicles and better maintain their vehicles than lower income people. According to this relationship, fleet age can be controlled for based on the income level for residents. Although Tarrant County's personal income per capita is slightly higher than Bexar County, it is not high enough to have a significant impact on the study.

Design Weaknesses

Finding a suitable comparison group is the primary threat to this research. No two counties are identical in every respect. Therefore, this research selected the comparison group based on close similarities in the population of the two counties.

The number of observations can also be considered a setback for this research. Bingham and Felbinger (2002, 123) suggests having numerous observations before and after the program is implemented strengthen this type of design.

Although this study identified carbon monoxide and volatile organic compounds being closely linked to motor vehicle emissions, they are not the only source for these pollutants. There are stationary sources that also emit these pollutants. Additionally, even though Bexar and Tarrant counties registered vehicle trend was similar, the growth of stationary polluting sources could not be identified in each county. Therefore, this may have some impact on overall emission levels for each county.

The last threat this research faces is fleet age. It is very difficult to determine each counties fleet composition. Every vehicle year, make, model and maintenance history would need to be obtained to determine if the vehicle fleet is truly similar for both counties. Even with these weaknesses, this research is still very strong in fulfilling its purpose.

Statistics

The interrupted time-series regression for this project compares two regression lines before and after the program is implemented in 2002. Of the 9 independent variables in this study, 7 are manually created. Definition, coding and computation of these 7 independent variables can be found in Table 4.1. The two independent variables (income per capita and registered vehicles) are used as covariants to control for the differences in population and age of the vehicle fleet in the two counties.

Human Subjects Protection

This research project uses secondary analysis of publically available data. Since there is no human involvement in this project it has received IRB exemption with a number of EXP2011M1891.

Chapter 5: Results

Chapter Purpose:

The purpose of this chapter is to explain the results of the statistical analysis. This chapter displays the results of the interrupted time-series regression in graph and table form. The results show the impact, if any, of the vehicle inspection and maintenance program on Tarrant County.

Regression Analysis

The first regression tested the first hypothesis regarding the level of carbon monoxide. Figure 5.1 displays the carbon monoxide trend during the observation period. Even though the carbon monoxide levels of both Tarrant and Bexar counties do not seem to be different from each other prior to 2002, Tarrant County was classified non-attainment because of high levels of ozone. As the graph shows, carbon monoxide was on a downward trend in both counties before the inspection and maintenance program was implemented in Tarrant County and continued to decline in fiscal year 2002 when the program went into effect. The interruption line refers to when the program was implemented. However, both counties experienced an increase in carbon monoxide during fiscal year 2003, Tarrant County did not begin to experience decline again until fiscal year 2006.

Table 5.1 displays the results of the regression analysis for carbon monoxide. For a variable to have an impact it must have a significance level less than .05. However, none of the coefficients resulted in any significance. The coefficient time resulted in a significance level of .482. Since this coefficient is not significant, it is concluded that there was no trend in carbon monoxide before the inspection and maintenance program went into effect in Tarrant County.

The dummy coefficient resulted in a significance level of .186. Since this coefficient is not significant, it is concluded that Tarrant County did not experience short term change after the program was implemented. The coefficient program resulted in a significance level of .919. This means there was no difference in Tarrant County's carbon monoxide trends before and after the program went into effect.

The coefficient group * time represents the difference between Bexar County's carbon monoxide level and Tarrant County's carbon monoxide level before the inspection and maintenance program went into effect. This coefficient resulted in a significance level of .654. Since this coefficient is not significant, it is concluded that there was no difference between the slopes of each county before the program went into effect. The coefficient group * dummy resulted in a significance level of .936. Since this coefficient is not significant, it is concluded that there was no difference between the immediate increases of carbon monoxide between the two counties.

The final coefficient group * program is the most important coefficient, because it considers the difference between the slopes of the two counties before and after the program was implemented. The coefficient resulted in a significance level of .809. Since this coefficient is not significant, it is concluded that the program ultimately did not significantly impact carbon monoxide levels in Tarrant County.

Figure 5.1: Carbon Monoxide Trends

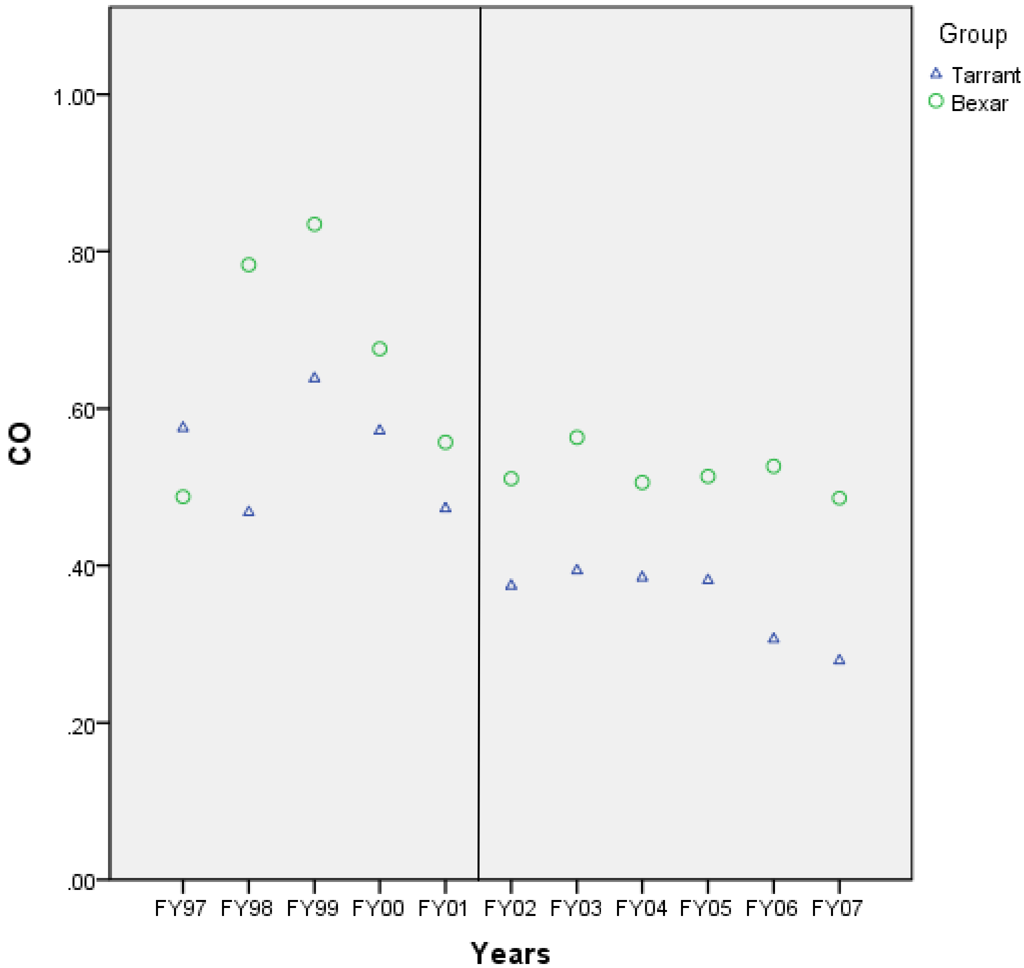


Table 5.1: Table of Regression Analysis Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.271	1.410		.902	.385
	Time	.066	.091	1.542	.725	.482
	Number of registered Vehicles	1.301E-6	.000	1.220	.947	.362
	Income per capita	-8.582E-5	.000	-2.676	-1.162	.268
	Dummy	-.285	.203	-1.051	-1.403	.186
	Program	.004	.039	.064	.104	.919
	Group	-.057	.231	-.213	-.249	.808
	Group * Time	.019	.042	.539	.459	.654
	Group * Dummy	-.013	.158	-.043	-.082	.936
	Group * Program	-.013	.054	-.176	-.247	.809

a. Dependent Variable: CO

b. $R^2 = .749$

c. F = 3.97

The second regression tested the second hypothesis regarding the level of volatile organic compounds. Figure 5.2 displays the VOC trend during the observation period; which is fiscal year 1997 through fiscal year 2007. The interruption line refers to when the program was implemented. As the graph shows, VOC for Bexar County has remained low during the entire observation period. Tarrant County VOC levels were high but reflected a declining trend, except during fiscal year 2000. In fiscal year 2003, Tarrant County's VOC level dropped drastically due to several environmental policies being implemented. These policies are discussed in chapter 6 under the 'limitations of study' section.

Table 5.2 displays the results of the regression analysis for VOC. None of the coefficients resulted in any significant impacts. The coefficient time resulted in a significance level of .244. Since this coefficient is not significant, it is concluded that there was no trend in VOC before the inspection and maintenance program went into effect. It is possible that the peak in fiscal year 2000, resulted in the analysis not recognizing the downward trend.

The dummy coefficient resulted in a significance level of .915. Since this coefficient is not significant, it is concluded that Tarrant County did not experience short term change after the program was implemented. The coefficient program resulted in a significance level of .925. It is concluded that there was no difference in Tarrant County VOC level before or after the implementation of the inspection and maintenance program.

The coefficient group * time represents the difference between Bexar County's VOC level and Tarrant County's VOC level before the inspection and maintenance program went into effect. This coefficient resulted in a significance level of .540. Since this coefficient is not significant, it is concluded that there was no difference in slope between the two counties before the program went into effect. The coefficient group * dummy resulted in a significance level of .330. Since this coefficient is not significant, it is concluded that there was no significance in the immediate decline of voc for Tarrant County.

The final coefficient group * program is the most important coefficient, because it considers the difference between the slopes of the two counties before and after the program was implemented. The coefficient resulted in a significance level of .858. Since this coefficient is not significant, it is concluded that the program ultimately did not impact VOC levels in Tarrant County, but instead the levels were impacted by other factors or variables.

Figure 5.2: Volatile Organic Compound Trends

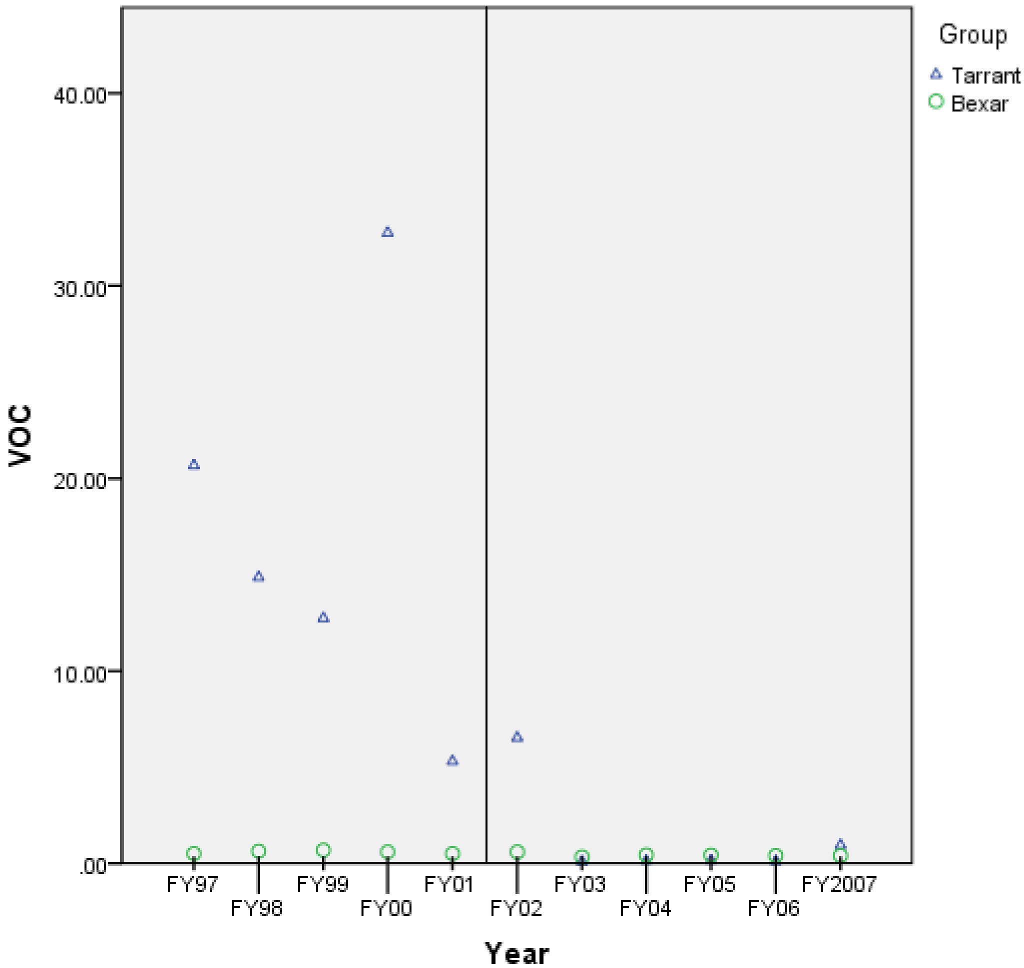


Table 5.2: Table of Regression Analysis Results

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-74.695	87.359		-.855	.409
	Time	-6.883	5.621	-2.632	-1.224	.244
	Number of registered vehicles	1.182E-5	.000	.181	.139	.892
	Personal income per capita	.003	.005	1.741	.748	.469
	Dummy	-1.371	12.572	-.083	-.109	.915
	Group	-9.583	15.615	-.579	-.614	.551
	Program	.228	2.389	.059	.095	.925
	Group*Time	1.655	2.621	.831	.631	.540
	Group*Dummy	9.934	9.792	.535	1.014	.330
	Group*Program	-.608	3.315	-.132	-.183	.858

a. Dependent Variable: VOC

b. R^2 = .743

c. F = 3.86

Chapter Summary

Implementation of the vehicle inspection and maintenance program does not appear to have a significant impact on carbon monoxide and VOC levels in Tarrant. Two covariants were used in the regression analysis. Number of registered vehicles was used to control for the population size of each county, for each respective fiscal year. The number of registered vehicles was not significant in either regression analysis. Personal income per capita was used to control for fleet age. Earlier chapters of this research discussed the possible link between vehicle characteristics and income. Personal income per capita was not significant in either regression analysis. None of the coefficients resulted in any significance, indicating that overall the inspection and maintenance program did not impact carbon monoxide and VOC levels for Tarrant County.

Chapter 6: Conclusion

Research Summary

The purpose of this research project is to assess the impact of the vehicle inspection and maintenance program on carbon monoxide and volatile organic compounds levels for Tarrant County Texas. The first chapter introduces the significance of motor vehicle emissions as well as the research purpose. The second chapter provided background information on emission testing development and its adoption in Texas. Chapter three discussed previous motor vehicle emission studies and developed hypotheses to be tested in this study. Chapter four operationalized the hypotheses and explained the technique used to tests the hypotheses. Chapter five explained the results of the regression analysis. This chapter will assess the findings of this study as well as its limitations. This chapter also offers suggestions for future research on motor vehicle emissions and inspection and maintenance programs as well as suggestions for policy makers.

Assessment of Findings

The findings indicate that the vehicle inspection and maintenance program did not have a significant impact on carbon monoxide and VOC levels in Tarrant County. The analysis showed that carbon monoxide levels were decreasing in both counties before the inspection and maintenance program was implemented and actually increased immediately after implementation. This result is explained in the next section titled, limitations of the study. VOC levels for Tarrant County were also on a decline before the implementation of the vehicle inspection and maintenance program and declined drastically after the program began. However, this decline is not necessarily linked to the implementation of the inspection and maintenance program because there is a lag in policy implementation and actual results. The results are further explained in the next section of this chapter.

Earlier studies linked income to motor vehicle emissions by vehicle characteristics. This study used personal income per capita for each county to control for fleet age. However, this covariate was not significant in either hypotheses as shown in Table 5.1 and 5.2.

To control for population size and growth for each county, number of registered vehicles for each observed fiscal year were used. After using it as a covariate in both regression analysis, it did not appear to be significant in Table 5.1 and 5.2.

Overall, the research indicates that the vehicle inspection and maintenance program did not have a significant impact on carbon monoxide and VOC levels. The research also indicates that personal income per capita and number of registered vehicles did not have a significant impact on carbon monoxide and VOC levels.

Limitations of the Study

The first limit of this research is the threat of history. The threat of history is when some other event occurred during the same time as the intervention. In 1999, Tarrant County was deemed non-attainment for ozone. As a result, TCEQ activated a State Implementation Plan (SIP) for the region in 2000, to get them to attainment status. Several environmental policies were adopted to reduce ozone pollution. These policies also affected VOC levels, causing them to rapidly decline during the observation period of this study. During this same period fuel reformulation went into effect, which further reduced VOC levels. However, when fuel was originally reformulated, it reduced efficiency by 1 to 3 miles per gallon. These reductions in fuel efficiency possibly lead to carbon monoxide increases during the observation period considering both counties were subject to the same reformulated fuel.

An emission trend study for 1990-2010 reported rapid VOC decline can also be attributed to the decline in oil and gas production activity in Texas (Bollman et al. 2007, 5). This study also indicates carbon monoxide declined because of a burn ban implemented in 1997, but was later lifted once air quality improved. Other air pollutating categories, including residential wood also implemented emission reduction strategies to further decrease carbon monoxide levels. Unfortunately, the exact decline attributable to these threats of history are unknown. Therefore, we conclude that all of these programs may have contributed to the decline in VOC levels and possibly carbon monoxide levels.

The second threat to this research is instrumentation, which are changes in record keeping procedures. During the observation period for this study, Texas has brought new monitors online and taken older monitors offline. Therefore, as emission monitoring technology changed, data may not have been recorded the same. Also, the software and technology the EPA uses to record gathered data has changed over the course of the years. Considering this threat, it is possible that some of the data years may not have been recorded the same as other years of data.

Suggestions for Future Research

In the future, researchers should manually gather emission data from the originating source. Earlier literature suggested that vehicles that fail inspections may only get generic repairs to pass the inspection, not necessarily to lower emissions. Therefore, to truly determine the impact of the vehicle inspection and maintenance program on emission levels, a study by Okmyung Bin 2003, should be replicated. Bin documented the vehicle characteristics, carbon monoxide and VOC level for each vehicle at various inspection stations (Bin 2003, 217). Bin also uses a regression analysis to interpret the data obtained.

Since the program has been ongoing for 12 years, future studies should gather data up to the current year to analyze. More observation periods will strengthen the research and remove the history threat to validity.

Finally, future studies should obtain a true comparison group. The comparison group should have similar fleets, vehicle population, carbon monoxide and VOC levels before the program goes into effect. Once the program is implemented, vehicle population and fleet characteristics should still remain similar to eliminate their influence.

Suggestions for Policy Makers?

Air pollution has been a growing problem in the United States since the industrial revolution. With more vehicles on the road around the globe, policies need to be adopted to reduce motor vehicle emissions. The inspection and maintenance program should be studied in depth across the United States to determine if it truly has an environmental impact; especially since there is a price increase for vehicle owners that are subject to emission testing. The aim should be to find global solutions to motor vehicle emissions and alternative energy sources. The immediate strategies for policy makers would be to introduce low-carbon fuels, improve transportation system efficiency, and reduce emission intensive travel activity. However, these suggestions are not only for policy makers, but for every individual.

Federal policy suggestions include increasing fuel standards, tax and pricing incentives for cleaner burning fuel, and additional funding for research and development. By investing in research and development for alternative fuels, vehicle manufacturers will be more susceptible to adopt them if a supplier is available. Federal regulation can also help ensure the fuel and vehicle manufacturer sectors work together to reduce foreign dependence on oil.

Overall, we all need to realize climate change is real and greenhouse gases are a major contributor. In order to preserve the environment, human health and eco-systems, changes need to be made in the way we view transportation. More research needs to be conducted to determine the best way to influence emission reductions in every sector of the transportation industry. This is certainly an area that will continue to change and impact the quality of life for millions of people around the globe.

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