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DRAFT FOR REVIEW

Generally Applicable Emission Performance Measures

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Overview

The purpose of this subtask was to develop a framework and identify generally applicable performance measures that could be used by the Texas Department of Transportation (TxDOT) to track progress towards air quality (AQ) and emissions-related goals. The aim of the framework and performance measures developed is to provide a holistic snapshot of air quality concerns that can be tracked by transportation-related measures, extending beyond the usual conformity-determination and emissions inventory approaches to quantifying performance measures based on a range of transportation and air quality issues. Thus, consideration was given to issues such as fleet characteristics and travel characteristics, which form the underlying source of emissions and poor air quality. For example, vehicle attributes such as age and fuel efficiency affect the amount of emissions, as do parameters such as total miles of travel and congestion.

As a part of this task, researchers identified a set of air quality goals relevant to the transportation sector and to TxDOT, and associated performance measures. Both the transportation system in Texas and TxDOT-specific operations and activities were taken into consideration. The final framework was developed with two tracks, one focusing on agency-level performance measures (i.e. those specifically relevant to issues TxDOT can control), and another on system-wide performance measures. It is important to give consideration to both these aspects - while system-wide measures contribute to knowledge of actual air quality performance across the state, a state department of transportation (DOT) like TxDOT has considerably more control over their own performance than system-level issues, and may want more in-depth tracking of parameters they can actually control.

This introductory chapter discusses the following topics, which are relevant to the development of a framework and set of performance measures for emissions and air quality:

- Background on air quality, emissions, and the role of transportation;
- Emissions of interest and emissions trends;
- Current air quality legislation and transportation conformity;
- Transportation-related emissions in Texas specifically, including current control measures;
- Performance measurement overview;
- Performance measurement as it relates to emissions and air quality;
- Data and data sources; and
- Framework development.

Following chapters of this report then present the development of a performance measurement framework (including goals and performance measures), quantification of selected performance measures, and results and conclusions. A list of commonly-used acronyms and abbreviations is provided in Appendix A.

Background on Air Quality, Emissions, and Transportation's Role

Air quality has increasingly become an important consideration both nationally, and worldwide. However, consideration of air quality is no longer limited to the six criteria pollutants covered by the National Ambient Air Quality Standards (NAAQS). Now, air toxics and greenhouse gases (GHGs) are cause for concern as well (*1*). The United States Environmental Protection Agency (EPA) has identified twelve major sources of emissions, of which on-road vehicles are the most significant transportation-related category (*2*). Several other sources, such as non-road equipment and road dust, may tie indirectly to transportation in general. Overall, it is estimated that transportation contributes significantly to air pollution in the United States (*3*). Therefore, when addressing air quality, the transportation sector should be given significant consideration.

Emissions are considered a negative externality of transportation, in that the cost associated with poor air quality is borne by society as a whole, rather than just the users of the transportation system (*3*). The effects of these emissions can be far-reaching or experienced near the source. At a local level, negative effects on human health are an issue, with as many as six out of ten Americans believed to reside in areas with unhealthy levels of air pollution (*4*). The impacts of different pollutants may also be more far-reaching, however. Regional impacts, such as acidification of rain, and global impacts, such as stratospheric ozone depletion, are linked to emissions as well (*5*). However, air quality issues from the local to the global level are affected by more than just vehicular emissions rate and the miles traveled. There are a number of other influential factors when determining the effects of emissions, including dispersion characteristics, topography, meteorological factors, and the presence of natural removal processes, or "sinks" (*6*).

Characteristics and Trends of Particular Emissions

The overall concerns with transportation-related emissions and its impacts can be grouped as:

> Emissions of pollutants – i.e. those with human health and environmental quality impacts
>
> Emissions of greenhouse gases – i.e. those like carbon dioxide (CO_2), which do not have an immediate local impact, but are still a concern from a long term global perspective.

One positive occurrence in terms of transportation-related emissions trends is that total emissions have been found to have stabilized or even decreased significantly (in the case of certain pollutants). This decrease has occurred despite an increase in fuel consumption by road transportation modes over the years (*7*). Between just 2000 and 2008, for example, national emissions of nitrogen oxides (NOx) from highway vehicles have decreased from about 8.4 million tons to just over 5 million (*8*). At the same time, fuel consumption has increased approximately 6 percent nationally (*9*, *10*). Regulations of the internal combustion engine, such as the dissemination of the catalytic converter, have resulted in vehicles that emit less than in the past. Vehicle fuel efficiency has also improved. On the other hand, road congestion does not appear to be improving, which can add to emissions. A study conducted by TxDOT in Houston found that there was a slight increase in emissions of volatile organic compounds (VOCs) and NOx due to nonrecurring congestion caused by traffic crashes (*11*). In addition, as the amount of vehicles on the road continues to grow, the emission of CO_2 is proving to be an important issue as well. Carbon dioxide increases proportionally with transportation usage, in the case of combustible-fuel based transportation. CO_2 is a greenhouse gas believed to contribute to global climate change. On a more positive note, with increasing fuel efficiency, the amount of CO_2 emitted per vehicle should be far less, since emission of CO_2 is primarily the result of fuel combustion. Additionally, increased usage of hybrid or alternative fuel vehicles should contribute to reduction in CO_2 emissions.

In terms of pollutant emissions, there are a total of six "criteria pollutants" which are regulated by the EPA through the NAAQS - carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and particulate matter, which can include both "fine" particles with diameters less than or equal to 2.5 micrometers ($PM_{2.5}$) and particles with diameters less than or equal to 10 micrometers and greater than 2.5 (PM_{10}) (*12*). Rather than being directly emitted, ozone is typically formed from a chemical reaction of NOx, VOCs, and sunlight. The other pollutants are direct emissions that result from transportation to varying degrees. For example, the transportation system contributes anywhere from 70 to 90 percent of CO emissions, but only accounts for about 5 percent of SO_2 emissions (*7*). Transportation also accounts for about one third to one half of other criteria pollutants, although lead emissions decreased 95 percent between 1980 and 1999 due to EPA regulations (*13*). Additional emissions of concern include mobile source air toxics (MSATs). Air toxics are pollutants that are either known or expected to cause serious health problems, including cancer, birth defects, lung damage, immune system damage, and nerve damage (*14*). Although there are no NAAQS for MSATs, the EPA previously identified six that have the greatest health impact, out of 21 chosen in 2001 (*15*). These include the known carcinogen benzene, and potential carcinogens 1,3-butadiene, formaldehyde, acrolein, acetaldehyde, and diesel particulate matter (DPM). Benzene is emitted in unburned fuel or as vapor when gasoline evaporates, while the others are byproducts of incomplete combustion or chemical reactions.

All of these pollutants pose a serious risk to both the environment and peoples' health. People that live very near to a highway, railroad, or airport are especially at risk, because concentrations of hazardous air pollutants increase significantly the closer one gets to these sources, and they would be exposed very often (*15*). Tables summarizing information on some of the major pollutants are located in Appendix B. Information includes potential health effects and environmental effects. A table is also included that summarizes aspects of some environmental consequences of air pollution—smog, acid rain, and odors.

The consideration of greenhouse gases is also an important transportation and emissions related issue. GHGs are atmospheric gases that absorb and emit infrared radiation—the basic cause of the greenhouse effect, which is linked to climate change implications for the future. The transportation sector accounts for approximately one third of all U.S. GHG emissions, and has accounted for almost half of the net increase since 1990 (*16*). Based on data from 1990 to 2006, "the primary greenhouse gas emitted by human activities in the United States was CO_2, representing approximately 85 percent of total greenhouse gas emissions" (*17*). Within transportation, about 66 percent results from gasoline combustion, 16 percent from diesel, and 15 percent from jet fuel (*8*). Some information on CO_2 is also included in Appendix B.

Current Air Quality Legislation and Transportation Conformity

The first federal legislation involving pollution was the Air Pollution Control Act of 1955. However, air pollution control was not included until the Clean Air Act of 1963. The most recent revisions to the Clean Air Act took place in 1990 (*18*). Under the Clean Air Act (CAA), the EPA sets primary air quality standards to protect public health, and secondary standards to protect public welfare from adverse effects (including effects on vegetation, soil, plants, water, wildlife, buildings/national monuments, visibility, etc.) (*19*). As stated previously, the EPA currently has national ambient air quality standards for six criteria pollutants—carbon monoxide, ozone, lead, nitrogen dioxide, particulate matter, and sulfur dioxide. The current standards are shown in Table 1.

Table 1: Current National Ambient Air Quality Standards (*20*)

Pollutant	**Primary Standards**		**Secondary Standards**	
	Level	**Averaging Time**	**Level**	**Averaging Time**
Carbon Monoxide	9 parts per million (ppm) (10 mg/m^3)	8-hour	None	
	35 ppm (40 mg/m^3)	1-hour		
Lead	0.15 µg/m^3	Rolling 3-Month Average	Same as Primary	
	1.5 µg/m^3	Quarterly Average	Same as Primary	
Nitrogen Dioxide	53 parts per billion (ppb)	Annual (Arithmetic Average)	Same as Primary	
	100 ppb	1-hour	None	
Particulate Matter (PM_{10})	150 µg/m^3	24-hour	Same as Primary	
Particulate Matter ($PM_{2.5}$)	15.0 µg/m^3	Annual (Arithmetic Average)	Same as Primary	
	35 µg/m^3	24-hour	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour	Same as Primary	
	0.08 ppm (1997 std)	8-hour	Same as Primary	

	0.12 ppm	1-hour	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Average)	0.5 ppm	3-hour
	0.14 ppm	24-hour		

These six pollutants are referred to as ‘criteria’ pollutants because the EPA “regulates them by developing human health-based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels” (*21*). They may also be damaging to property. The EPA must review the latest scientific information and standards every five years, and make changes as needed (*22*). Currently, particulate matter and ozone are considered the greatest health threats out of these six. Under the Clean Air Act, states must develop a State Implementation Plan (SIP) if any area within the state is classified as ‘nonattainment’—that is, the area has air pollution levels that “persistently exceed” the NAAQS for at least one of the six criteria pollutants. An SIP explains how the state will comply with and meet the NAAQS within the prescribed CAA schedule (*23*). Emission reduction targets are assigned for stationary sources, area sources, and mobile sources. Within the mobile source category, Transportation Control Measures (TCMs) are developed to reduce vehicle emissions and the help the agency attain air quality goals (*24*).

Transportation agencies must demonstrate conformity with planning, transportation improvement programs (TIPs), and projects funded or approved by the Federal Highway Administration (FHWA) or the Federal Transit Administration (FTA). To determine conformity, the agency must model resulting emissions, and show that they are within specified limits (*25*). In other words, the given transportation activity must not “cause new air quality violations, worsen existing violations, or delay timely attainment” of NAAQS (*26*). This initial determination is conducted by Metropolitan Planning Organizations (MPOs), although state agencies may help analyze emissions past MPO boundaries. If conformity is not demonstrated, the use of Federal transportation funds is restricted to only certain kinds of projects, such as ‘exempt projects’ (like safety improvements) and TCMs that were already approved in an SIP (*27*).

Some areas have chosen to enter into an Early Action Compact (EAC) with EPA, in order to have the flexibility to develop their own air pollution control strategies to meeting the 1997 8-hour ozone standard. To be eligible for this, the area must have already met the national 1-hour ozone standard. The goal is that EAC areas will begin reducing air pollution about two years earlier than they would have otherwise. The incentive for these communities is that, as long as they “meet agreed upon milestones, the impact of nonattainment designation for the 1997 8-hour ozone standard will be deferred, which means that certain CAA requirements, such as controls on new sources, will not apply” (*28*).

Transportation-Related Emissions in Texas – Current Status and Control Measures

Currently in Texas, the Dallas-Fort Worth (DFW), Beaumont-Port Arthur (BPA), and Houston-Galveston-Brazoria (HGB) areas are classified as nonattainment per the NAAQS for 8-hour ozone emission standards, with the HGB area considered to be in severe nonattainment. The Austin-San Marcos, San Antonio, and Northeast Texas areas are all Ozone EAC areas. The El Paso (EP) area is considered nonattainment for PM_{10}, and is classified as a maintenance area for CO. These areas are shown in Figure 1.

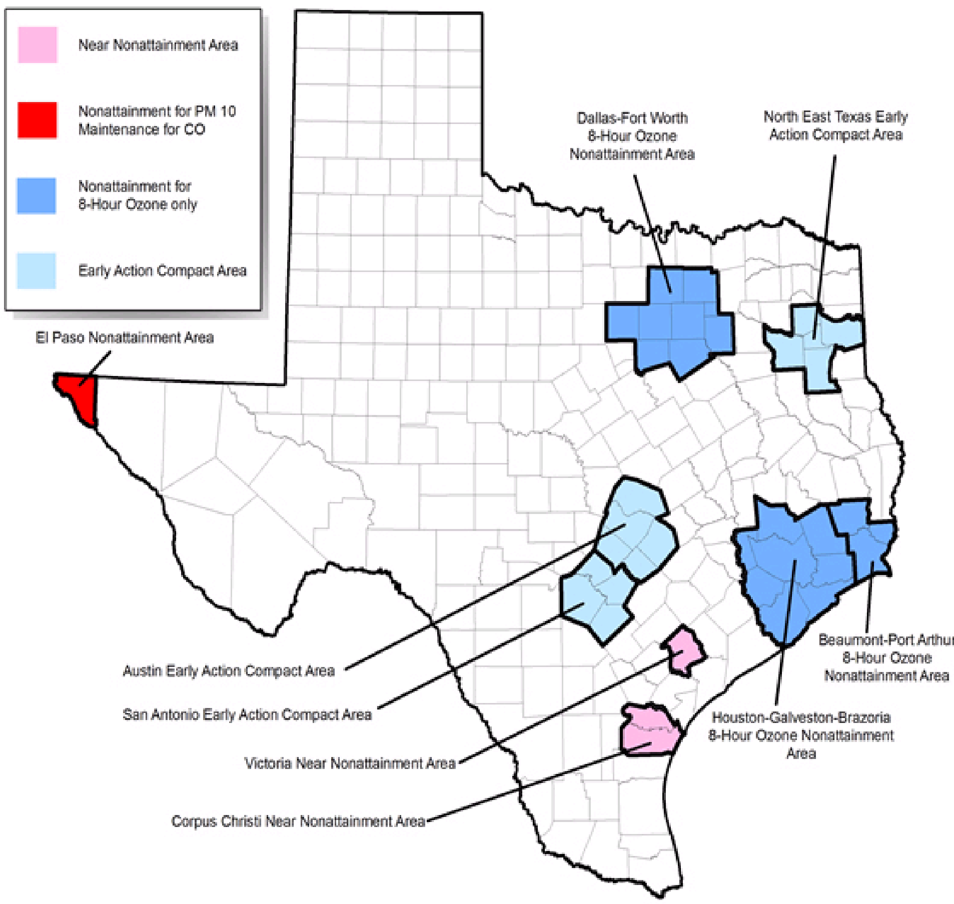

Figure 1: Texas nonattainment and near-nonattainment areas (*29*).

This figure also shows that the Victoria and Corpus Christi areas are in danger of becoming nonattainment areas. For reference, nonattainment areas and nonattainment counties include:

Beaumont-Port Arthur (BPA), moderate nonattainment for 8-hour ozone

Hardin County	Jefferson County	Orange County

Dallas-Fort Worth (DFW), moderate nonattainment for 8-hour ozone

Collin County	Dallas County	Denton County

Ellis County	Kaufman County	Rockwall County
Johnson County	Parker County	Tarrant County

El Paso (EP), moderate nonattainment for PM_{10}

El Paso County

Houston-Galveston-Brazoria (HGB), severe nonattainment for 8-hour ozone

Brazoria County

Chambers County

Fort Bend County

Galveston County

Harris County

Liberty County

Montgomery County

Waller County

Additionally, the Texas Commission on Environmental Quality (TCEQ) has also summarized what these different areas are doing to address air quality problems in terms of transportation related solutions as shown in Table 2.

Table 2: Control Measures Utilized in Texas for Mobile Emissions Sources (*30*)

Control Measures	**Area**									
	Nonattainment for 8-Hour Ozone			**NA for PM 10**	**Early Action Compact Areas**			**Near Non-attainment**		**Others**
Mobile Source	Houston-Galveston-Brazoria	Dallas-Fort Worth	Beaumont-Port Arthur	El Paso	Northeast Texas	Austin-San Marcos	San Antonio	Corpus Christi	Victoria	
Locally Enforced Vehicle Idling		X				X				
Vehicle Inspection and Maintenance	X	X	X			X				
Texas Emission Reduction Plan	X	X	X	X	X	X	X	X	X	
Texas Low Emission Diesel	X	X	X		X	X	X	X	X	X
Low Reid Vapor Pressure (RVP) Gasoline				X	X	X	X	X	X	X
Reformulated Gasoline (RFG)	X	X								
Voluntary Mobile Emissions Reduction Program (VMEP)	X	X								
Transportation Control Measures	X	X								
Texas Clean Fleet (TCF) Program	X	X		X						X
Speed Limit Reduction	X	X								
Large Non-Road Spark-Ignition Engine Standards	X	X	X	X	X	X	X	X	X	X
California NTE Heavy-Duty Diesel Engine Emission Standards	X	X	X	X	X	X	X	X	X	X
Vehicle Anti-tampering Restrictions	X	X	X	X	X	X	X	X	X	X

Overview of Performance Measurement

In general, performance measures (or indicators) are measurable criteria that can be used to evaluate progress toward achieving goals. Performance measurement is described by the U.S. General Accounting Office (GAO) as “the ongoing monitoring and reporting of program accomplishments, particularly progress toward pre-established goals” which may address processes, outputs, or outcomes (*31*). The terms ‘performance measure’ and ‘performance indicator' are often used interchangeably in literature, or are attributed conflicting meanings. In this research, 'indicators' are considered as aspects of performance desired for study, while 'measures' attempt to quantify and evaluate these performance indicators. In other words, "a performance measure is composed of a number and a unit of measure", and can be seen as proving specific detail to an indicator (*32*).

Performance measurement can improve agency accountability, improve resource allocation efficiency, give an opportunity to advocate for a change, and is recognized in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) as a critical part of long-range planning for transportation (*33*). Agencies can track their progress and monitor quality, as well as system operations. Performance measurement has been used by public agencies for many years, but is now becoming increasingly important, especially as citizens demand accountability and transparency. In addition, performance measures used by public agencies typically related only to areas directly under the agency's control. For a transportation agency, that could include capacity, bridge condition, and pavement quality. However, transportation decisions are increasingly being made in light of broader concerns, such as ecology, economic development, and quality of life (*1*). Although transportation is not the only factor that affects these areas, and efforts undertaken by other agencies may overlap with the programs of the transportation agency, these issues cannot be ignored. Unfortunately, performance measurement of these areas is more complex, since many environmental and social issues are difficult to quantify.

Types of Performance Measures

Different types of performance measures exist. Primarily, output and outcome measures are used. Outcome measures are usually desirable, as they actually provide an indication of whether desired outcomes were achieved (often something the agency wants to either maximize or minimize); whereas output measures just provide information on an individual activity related to the achievement of a desired outcome. In other words, outputs are what the program or agency actually did, while outcomes are the consequences of what it did (*34*). Output measures are usually much easier to define and track, however, and are more often under direct agency control (*1*). Thus, they afford the agency an opportunity for 'proactive management' of the factors involved (*35*). An outcome is usually aggregated from output measures, so the "difficulty lies in measuring these outcomes and determining a causal relationship with transportation outputs" (*33*). Outcomes may also be impacted by side effects external to measured outputs or other actions of the agency. Outcome measures can also be further designated as intermediate or long-term (i.e. more short term accomplishments versus desired final result) (*34*). Intermediate outcomes typically contribute to the achievement of related long-term (or 'end') outcomes. Additionally, agencies are likely to have more control over intermediate outcomes than long-term ones, making them easier to strive for. Finally, even if an outcome can be fully determined, it still may not be known why or how the outcome occurred (*36*). Other types of performance measures include input measures, process or workload measures, timeliness measures, productivity or efficiency measures (typically a comparison outputs to inputs), demographic or other workload characteristics, explanatory information, and impacts (*1*, *34*).

Characteristics of Good Performance Measures

A 'good' performance measure requires a careful development process, which would give consideration to various desirable characteristics. Abstract measures are not very useful—rather, in order to extract any useful information, a decision-maker would need "a specific, comparative gauge, plus an understanding of the relevant context" (*37*). The necessary data related to the measure should be realistic and reasonably attainable, and "provide the means to monitor plan implementation and determine necessary changes throughout the process or at regular update cycles" (*33*). In addition, the measure should distinguish between means and ends, and should also eliminate confusion concerning which results are the most desirable (*38*). Table 3 lists and describes desirable characteristics of performance measures found in literature. However, selected measures should not just exemplify the above characteristics. Measures must also be consistent with the actual needs of the agency creating them, and be specifically suited to agency goals and actions (*39*).

Table 3: Characteristics Related to 'Good' Performance Measures (*1*, *34*, *39*, *40*)

Characteristics That Should be Considered to Create 'Good' Performance Measures	
Attribute	**Description**
Measurability (Realistic)	• Are required data, analysis methods, tools, and resources available? • Can the necessary level of accuracy be achieved for the measure to be usable? • How reliable are the data sources? • Would it be feasible to take field measurements either for performance monitoring or model calibration?
Simplicity/Clarity	• Can the measure be understood by the public, elected and appointed officials and policy makers, agency staff, and other transportation professionals?
Usefulness	• Is this measure actually useful to any stakeholders? • Does it directly measure the desired issue?
Objectivity/Validity	• Are the measures factually based, so that the values themselves are not debatable?
Controllability	• Can the measured characteristic actually be controlled, corrected, or otherwise influenced by the agency measuring it? • Does the agency have direct or indirect control, and is that control full or partial?
Relevance	• "Is the measure relevant to planning/budgeting processes? • Does the reporting of these measures happen often enough to give decision makers the information they need as often as they need it?" (*37*)
Consistency	• Is the measure reliable? • Is there sufficient consistency between measurement methods that current and past results can be compared?

Uniqueness	• Does the measure duplicate or overlap with another?
Ability to Forecast	• Do related forecasting methods currently exist, and, if so, are they easy to use? • Would projections of this measure into future scenarios be relatively realistic? Would it allow for future comparisons of projects or strategies?
Multimodality	• Are relevant and/or desired travel modes addressed by the measure?
Ability to Diagnose Problems	• Can this measure directly diagnose problems and their causes, or does it only indicate condition such that further study or action is necessary? • Is the measure aggregated so much that a 'black box' condition might occur? • "Is there a logical link between this measure and what actions/phenomena affect it?" (*37*)
Cost Effectiveness	• Is the cost of collecting and analyzing necessary data within budget and resource limitations?
Number	• Is the number of measures presented small enough for easy communication with stakeholders? • Conversely, are all goals addressed? A hierarchical structure could be used for more detailed analysis.
Addresses Desired Temporal Scale	• Can the measure be compared over or across time? • Can the measure discriminate between performance during peak and off-peak periods, as well as different daily conditions? • "Does the measure fit well with the time frame of analysis and action?" (*37*). Is the measure intended for long-range planning, or to assess short-term impacts of decisions?
Addresses Desired Geographical Scale	• Is the measure specifically useful at a regional, subarea, or corridor level; or can it be applied to all areas of the state, region, and/or local area? • Can the measure differentiate between freeways and other surface facilities?

Performance Measurement for Transportation Agencies

In recent years, the importance of implementing performance measurement in public agencies has become more recognized, as it has the potential to improve decision making, service delivery, program effectiveness, internal management, efficiency, and public accountability. Performance measurement became a requirement for most federal agencies with the creation of the Government Performance and Results Act of 1993. This act required each federal agency to develop a strategic plan which would include performance measurement aspects (*41*).

In like manner, state agencies, including transportation agencies, have begun to develop their own performance measures, covering both internal performance measures, which typically involve decision making within the agency (including ranking capital investment alternatives, evaluating programs, allocating resources within the agency, long-range strategic planning, near-term project programming, and alternative evaluation at the corridor or facility level), and external performance measures, which typically involve evaluation of the agency by an external agent (including comparable-agency benchmarking, performance-based budgeting, evaluation of agency performance and efficiency, allocation of budgets, etc.) (*40*).

In terms of transportation agencies, based on performance measurement programs in 12 DOTs and MPOs, Report 446 from the National Cooperative Highway Research Program (NCHRP) suggests that a successful performance measurement program should:

Begin with measures that are easy to implement;

Have commitment from top-level leadership;

Have the support of career-level managers;

Coincide with creation of a ‘performance measurement culture’ and employee accountability;

Link measure results with decision making and actions;

Include widespread responsibility for data collection, management, and analysis; and

Include cyclical reporting, especially to external stakeholders. (*1*)

Additionally, measures employed by the agency may focus either on actions and results internal to the agency, or on the transportation system as a whole. External (system) measures can be used to give an overall picture of the status of the transportation system, and could even be helpful in decision-making and project selection. Some external measures, such as vehicle-miles of travel, are also needed for emissions modeling. On the other hand, an agency may desire to focus more on internal measures, as the agency typically has more control over agency actions than on the overall transportation system. Agency actions and projects may not have a direct effect on the transportation system, which is also affected by various externalities. For example, freight movement would be useful to track, especially as it affects pavement quality. However, while a transportation agency could adopt policy or undertake projects to try to lessen freight movement; these efforts may or may not have an effect. Also, a change in freight movement could result from an externality such as gasoline price rather than a direct agency action. Thus, an agency cannot fully control all aspects of the transportation system, but has more control over agency and employee actions.

Performance Measures for Emissions and Air Quality

The previous section on performance measurement provided a general idea of what performance measurement is, and how transportation agencies can implement good performance measurement practices in their sector. Overall, existing examples of performance measurement related to emissions and air quality in the transportation sector are covered under the broader category of environmental performance measures. Minimization of air pollution is desirable in order to minimize adverse effects on the ecosystem, human health, structures, and even visibility. At the same time, however, goals such as mobility, accessibility, and economic development are desirable within the transportation field (*40*). Problems arise when these goals conflict, since in many ways they oppose each other. In fact, environmental goals may be overlooked by policymakers in the face of other societal concerns like mobility. The use of performance measurement could help ensure that environmental and air quality considerations "are being consistently and transparently considered in public policy" (*42*).

As part of NCHRP 25-25, agencies that dealt with transportation were investigated, and five were found to use environmental performance measures (two MPOs and three DOTs). The primary reason given was "the ability to evaluate existing programs and projects, and to communicate the results…within the agency" (*1*). Other motivations for environmental performance measures included benchmarking, assistance with agency resource allocation, and help identifying inefficiencies, among others. Thus, tracking environmental concerns could not only ensure that they are considered in decision making, but may also improve agency function.

Air quality is just one aspect that could be considered within environmental performance measurement. Other measure categories used by the five agencies mentioned above include water quality, wetland preservation, runoff, hazardous waste, environmental justice, and noise, among other subjects (*1*). Within the category of air quality alone, several approaches could be taken to develop measures. Measures could focus primarily on agency action in order to determine performance of the agency itself. For example, a measure could track agency timeliness in achieving certain air quality goals. On the other hand, measures could be used to track the performance of the transportation system as a whole. System-wide emissions could be tracked, for example, although such a measure would draw on others. In order to model emissions, aspects of the system would have to be known, such as vehicle miles of travel (VMT) in a desired location. Thus, air quality measures should not include just levels of different pollutants in the air. Measures should also include contributing factors such as vehicle travel and modal makeup. Extensive research was conducted to investigate the practices of other agencies and ideas from literature regarding air quality measures. Identification and discussion of these measures is included as part of the next chapter.

Data Sources and Needs

Data Requirements

Data requirements must be given consideration when selecting performance measures. Employees have limited time, and there may be a high cost associated with data collection, storage, and retrieval (*43*). Therefore, data that is already available to the agency is especially desirable. However, consideration should be given to data that may be more difficult or expensive to attain, but would be more useful or valuable to decision-makers. In addition to determining data requirements, a source for that data must be identified. Furthermore, the frequency of data collection and reporting should depend, at least in part, on the timing needs of decision-makers.

For successful use, data quality should be a high priority. Suggested criteria of data quality include accuracy (or rate of error), completeness, consistency, and currency (or "age of data relative to time of collection and collection frequency") (*43*). Common problems with data collection include:

Collecting so much data it cannot be used effectively;

Not collecting enough data;

Summarizing data to the point that it becomes meaningless;

Collecting inconsistent, conflicting, or unnecessary data;

Focusing only on the short-term;

Not making use of data for appropriate decisions; and

Collecting data too often, or not often enough. (*32*)

In addition, many methods exist for collecting data, although not all may be appropriate for the type of data needed. Potential methods include agency or project records, site inspections, surveys, and case studies, for example (*43*). In addition to applicability, the cost and time commitment must be considered when selecting a data source or method of collection.

Data Needs, Sources, and Analysis Tools

Performance measures related to emissions and air quality can draw upon a wide variety of data from different sources. Regional air quality management districts typically collect information on air quality and pollution. Consideration must be given to more than just VMT; however, results may not be entirely accurate due to assumptions made in the process. For example, measurement of CO_2 typically involves vehicle mileage and speed figures, as well as assumptions regarding average fleet fuel efficiency. Additionally, local authorities may exclude mileage on state or interstate facilities, and are unlikely to know exact fuel efficiency (*44*). Discrepancies may arise from modeling rather than measuring emissions as well. For modeling, passenger vehicles and heavy vehicles should be considered separately if possible. Different vehicle types have different emission rates, may travel at completely different speeds due to different typical driver behavior (*45*). In addition, on-road travel is not the only generator of mobile-source emissions. For example, idling of heavy-duty vehicles is a significant source of emissions, especially from heavy vehicles. In fact, research suggests that idling for a period of time produces more emissions and fuel consumption than shutdown/restart (*46*).

Modern technology can provide significant information about vehicular travel. Intelligent transportation systems (ITS) can provide information of vehicle volumes and turning movements. Automatic vehicle identification (AVI) can provide fairly disaggregated VMT and speed data, as it tracks individual vehicles over time, possibly with a global positioning system (GPS). Government agencies, such as the FHWA, the EPA, and the Bureau of Transportation

Statistics (BTS), are potential sources of system and fleet data. Data specific to Texas may be attainable through TxDOT or TCEQ.

Actual field emission data can be obtained through use of a portable emissions measurement system (PEMS). By sampling undiluted exhaust, a PEMS unit can measure concentrations of hydrocarbon (HC), CO, CO_2, nitric oxide (NO), oxygen gas (O_2), and $PM_{2.5}$ (NOx is calculated from NO) (*47*). On the other hand, much data may be produced through computer modeling and simulation. The MOBILE emission modeling software, first developed by the EPA in 1978, is used significantly to estimate grams per mile current and future emissions of HC/VOC, CO, NOx, particulate matter (PM), and SO_2 based on average speed at a national and local level, and for 28 different vehicle classes (*48*). Recently, MOVES2010 (MOtor Vehicle Emission Simulator) became available through EPA to replace MOBILE6.2 (*49*). This new system, which uses Vehicle Specific Power (VSP) for calculations, "will estimate emissions for on-road and non-road mobile sources, cover a broad range of pollutants, and allow multiple scale analysis" (*50*).

Developing a Performance-Measurement Based Framework for Air Quality and Emissions

A performance-measurement framework in the context of this research can be viewed as a means of formalizing goals and objectives and developing associated measures that are relevant to these goals and objectives, keeping in mind issues of data availability, scope, and characteristics of good performance measures. A basic description of the purpose of a framework is to "help organizations to define a set of measures that reflects their objectives and assesses their performance appropriately" (*51*). So, some sort of framework is needed, as a performance measure cannot "yield useful information until it is interpreted, explained, and set in context" (*52*). Environmental performance measures should be organized into a framework to assure that they "serve the purpose for which they are intended and to control the way they are specifically selected and developed" (*42*). Additionally, such a framework can be "integrated into broader performance assessment approaches" rather than focus only on performance measures (*42*).

Many different frameworks have been proposed to help organizations create a well-balanced set of measures. For example, one of the more popular frameworks is the Balanced Scorecard, first proposed by Kaplan and Norton in 1992, which focuses on financial, customer, internal, and innovation perspectives (*53*). Another framework is the Performance Prism, proposed by Kennerley and Neely (2002), which focuses especially on achieving stakeholder satisfaction (*51*). Many other proposed frameworks exist; and while many of the proposed frameworks are intended for the business sector, some ideas behind them are certainly applicable to the public sector as well. Within a public agency, a framework is needed to aid in the selection and evaluation of performance measures, and to help ensure that the measures support achievement of agency goals and objectives. While development of a generic performance measurement framework "for the public sector remains an elusive target", there have been attempts to create frameworks applicable for public agencies (*54*). A performance measurement matrix is a potentially useful tool for analysis—for example, a matrix developed for the Delaware DOT (DelDOT) had outcome measures related to planning goals, and output measures that related to specific policies and actions. The use of time-oriented graphs for presentation is also suggested, which would allow comparison of current performance to past performance, often in a rolling time period format (*35*). Such tools were utilized for this project, which more specific objectives tied to broader goals. Performance measures are then used to address each objective. The development of a framework such as this is discussed further in the next chapter.

Based on the findings discussed in this introductory section, it is seen that developing a framework for air quality and emissions performance measures for TxDOT requires the following issues to be taken into consideration:

- Criteria pollutants under the NAAQS, greenhouse gases, and any additional pollutants that may be covered by measures;
- Aspects of vehicle performance and technology that affect emission levels;
- Aspects of travel that affect emission levels;
- Transportation agency policy and actions that affect emission levels;
- Characteristics of 'good' performance measures;
- Data needs; and
- Framework organization.

CHAPTER 2: DEVELOPMENT OF A PERFORMANCE MEASUREMENT FRAMEWORK FOR AIR QUALITY AND EMISSIONS

Approach to Framework Development

The implementation of a performance measurement process requires the development of a framework to organize the measures and enable their evaluation on a consistent basis. This is commonly done through the use of a system of goals that translate down to objectives and strategies, and performance measures. The draft of the TxDOT 2011-2015 Strategic Plan provides an illustration of the relationship of goals, objectives, and measures, as shown in Figure 2. This graphic shows how goals are more general and cover more than objectives. Objectives and strategies provide more focus, and are wholly contained within the goal they address. Performance measures are contained within both an objective and a goal, and are most detailed and specific.

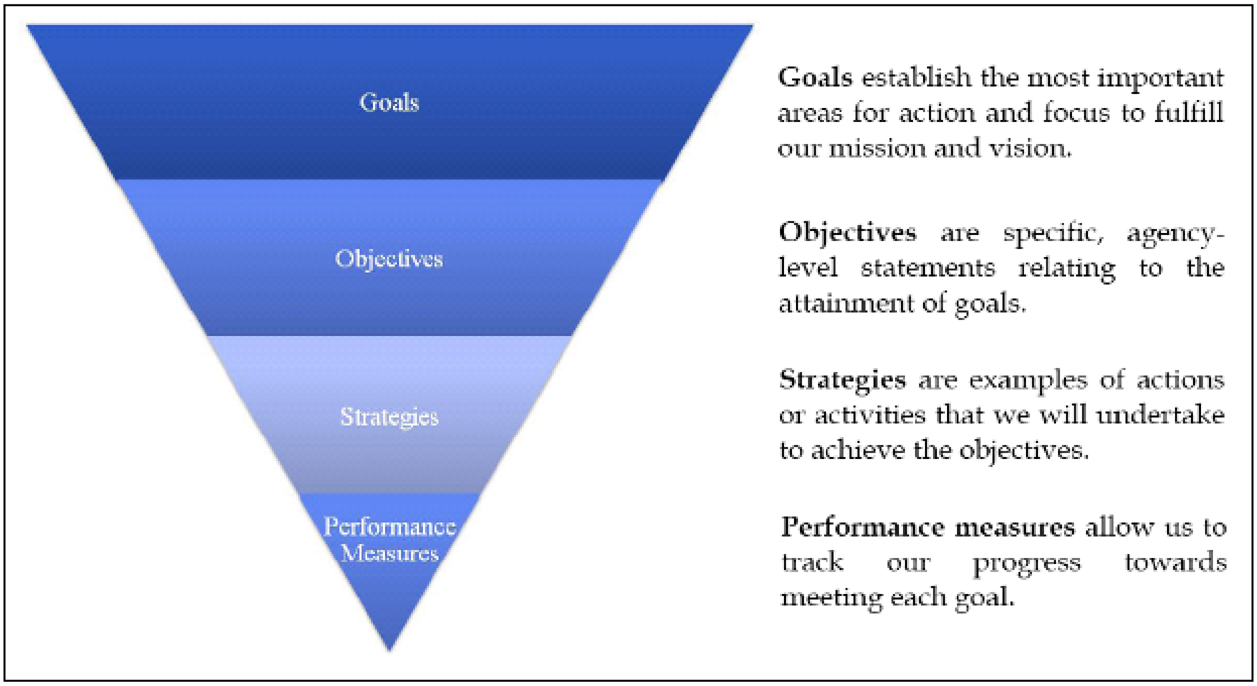

Figure 2: Illustration of goals, objectives, and performance measures (*55*).

As discussed in the introductory chapter, there are two aspects to air quality-related performance measures – 1) system-level measures that are of interest to the agency, but may not be within an agency's immediate control, and 2) agency-level measures that deal with issues directly controlled by TxDOT and its partner agencies. The framework developed as part of this research therefore included both an agency-specific track of objectives and measures, as well as a system-specific track, in order to differentiate between aspects of the agency and aspects of the transportation system as a whole. The framework included goals, objectives and performance measures, and the additional level of “strategies” shown in Figure 2 was eliminated. It was decided that a small set of agency-level indicators would be very useful to TxDOT, especially since TxDOT has greater control over its own actions than the actions of travelers across the state. This agency scorecard would help TxDOT monitor the progress of agency initiatives that can directly affect air quality. The general system measures can also be tracked if identified as being of interest. Figure 3 illustrates the general approach to the performance measurement framework developed. As shown, both objectives and indicators are separated between the transportation system and the agency. However, the overall air quality goals are common to both the system and the agency level.

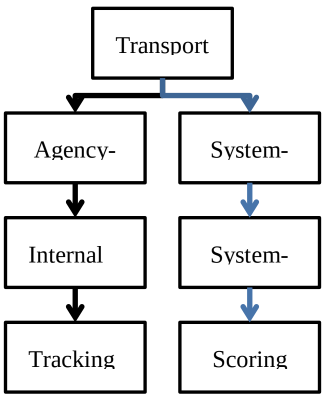

Figure 3: Illustration of new framework for goals, objectives, and indicators.

Thus, the framework addresses both the external and internal aspects of a transportation agency. In some ways, internal agency measures give a better indication of performance than measures that track the transportation system as a whole. Transportation agencies do not have complete control over all aspects of the system. For example, tracking the level of roadway congestion would be important, as congestion causes more emissions. However, while a DOT can try to implement demand management or other congestion mitigation measures, the relationship between agency action and congestion is not direct. Additionally, the transportation sector does not account for all pollutants emitted. So, while it is important to track ambient air quality levels, this concentration is not wholly affected by transportation alone.

Identification of Potential Goals, Objectives and Indicators

In order to develop further on the knowledgebase generated by the literature review, the following steps were carried out to identify applicable and relevant information:

Background and scoping exercise;

Identification of performance measures suggested in State DOT documents and literature; and

Development of goals based on this research, creation of objectives, and assignment of identified measures and addition of measures created by the research team.

The findings from these steps are summarized in detail in Appendices C through F.

Appendix C: State DOT Documents Reviewed—this table includes a list of all State DOT documents reviewed, as well as applicable findings;

Appendix D: Performance Measure List Categorized by Source and Type— suggested measures found in State DOT documents and other literature are (including references) organized into general categories and referenced to all sources;

Appendix E: Compendium of Performance Measures – Organized by Scope and Application—this compendium represents a useful reference of all initial performance measures considered, as well as guidance on potential application and scope; and

Appendix F: Development of an In-Depth Air Quality Performance Measurement Framework—the framework included represents one stage of the final framework development, and illustrates one evaluation method used to determine the best final measures.

The findings from the entire background exercise are briefly described below.

Background and Preliminary Scoping

In order to develop a performance measurement framework, an extensive search into current practices by other state departments of transportation was performed, based on documents available on state DOT websites. In addition, examples and suggestions from other literature sources were also considered for use as potential performance measures. Before initiating a review of these resources, a list of potential subject areas for performance indicators and measures was compiled, as shown below:

Vehicle inspection and maintenance;

Alternative fuels and/or cleaner diesel/gas;

Transportation control measures (interior and exterior to agency);

Funding devoted to achieving AQ goals;

Individual emissions;

Health effects;

Environmental effects;

Number of non-attainment days;

Number of ozone watch days;

People living in areas with poor AQ;

Employee actions to address AQ;

Construction and maintenance;

Amount of monitoring in attainment areas;

Use of mobile-source emission reduction strategies;

Planning for effects of climate change;

Public accountability;

Public fleet of vehicles;

- Public education/outreach, and approval;
- Project vs. planning levels;
- Crashes/incidents effect on AQ;
- Emissions related to water quality;
- Idling, truck stops; and ships at port;
- Plant/animal species;
- Emissions by mode type;
- Emissions from refueling;
- Alternative modes/carpooling;
- Older vs. newer vehicles in the fleet;
- Addressing bottlenecks, congestion; and
- Ferry emissions (Port Aransas and Galveston-Port Bolivar).

For the purposes of this research, only mobile sources of emissions were under consideration. After the literature review was conducted, the initial scope was determined to include mobile sources that the identified measures could apply to. This initial scope was also selected based upon mobile sources that TxDOT has interest in. The *Texas Guide to Accepted Mobile Source Emission Reduction Strategies* defines mobile sources as “moving objects that release pollution”, which are broken down into on-road and nonroad vehicles (*15*). The US EPA list of nonroad vehicles, engines, and equipment that it includes in the category of mobile sources is quite extensive. However, many of these categories, such recreational vehicles, farm equipment, and commercial equipment, were far outside the scope of this project. On the other hand, the *Texas Guide to Accepted Mobile Source Emission Reduction Strategies* does not include the nonroad sources of construction equipment and ships. However, these categories were given consideration since TxDOT does operate construction equipment and ferries. The mobile sources taken into consideration while developing the initial set of measures are shown in Appendix E. The inclusion of potential mobile sources provides a basis for the list of potential measures that follows in Appendix E.

Identification of Performance Measures Suggested in Literature

For this portion of the project, an extensive look was given to current practices by other state DOTs to identify air quality-related measures already in use or proposed. Measures already used by other DOTs have the advantage of already being scaled for state use, and applied specifically towards transportation. Research was conducted exclusively online, without any direct contact with a DOT. Documents of primary interest related specifically to performance measurement or air quality. For example, some DOTs had scorecards, dashboards, or quarterly performance reports online. However, other documents were perused as well, including strategic plans, research reports, annual reports, and long-range plans. However, many DOTs did not currently have performance measurement systems in place, or were just in the process of starting such a program. In addition, of the DOTs that do currently track performance, fairly few measures related to environmental concerns. Instead, measures appeared to focus primarily on more tangible aspects of performance, such as vehicle mileage, pavement quality, safety, and finance. Measures such as these are also potentially easier to measure than more abstract concepts such as air quality and environmental preservation. On the other hand, some aspects of performance, such as VMT and congestion, impact air quality and were given consideration. Consideration was also given to internal agency performance, which encompasses one 'track' of the framework approach. System-level measures may tie more directly to actual air quality, but an agency will have more control over most internal measures.

A number of both types of measures were found in DOT documents, even though most DOTs did not have any measures that even related to the environment in general. Potential measures were found from the following DOTs:

- CTDOT (Connecticut);
- IDOT (Illinois);
- Iowa DOT;
- MDOT (Maryland);
- MoDOT (Missouri);
- NDOR (Nebraska);
- NDOT (Nevada);
- VDOT (Virginia);
- WSDOT (Washington State); and
- WYDOT (Wyoming).

For reference, Appendix C contains a table that lists all documents reviewed, findings from those documents, and other potentially useful sources. An additional reference for internal agency measures is the TxDOT Clean Air Plan (CAP), which includes suggested actions the agency and its employees can take to reduce internal emissions (*56*). However, measures from this source are not listed here, so as not to overlap with an existing resource.

Finally, potential measures were identified in other literary sources. Several literature sources also had government origins. For example, guidance was obtained from both the US EPA and the European Environment Agency. Some of the measures were drawn from resources that focused on performance measurement as a whole, rather than specifically focusing on environmental impacts. Some of these included measures directly related to the objectives of this project. On the other hand, while many measures did not focus specifically on air quality or emissions, they did relate to air quality and emissions in some way. Similarly, several other resources focused on measures for 'sustainable transportation'. However, preserving the environment is one focus of sustainability, so these reports did offer many potential measures. The initial measure set, organized by subject, can be found in Appendix D, along with references to documents used.

Identification of Goals, and Definition through Objectives and Measures

Examples of measures in literature and other state DOTs provided guidance on general goals that might be considered within a framework. Based on this review, three broad transportation-related air quality goals were identified:

- Reduce transportation-related pollutant emissions;

Reduce transportation greenhouse gas (GHG) emissions;

Reduce the impact of transportation-related emissions on human health; and

The first two goals were identified as “source” goals—that is, measures under Goal 1 and Goal 2 should relate to factors that affect emissions. Goal 3 can be identified as a “receptor” goal, with measures that would reflect the effects of emissions, such as the effects on human health. Significantly, the goals are applicable both to a state transportation agency, and to the entire transportation system. In this way, these goals apply to the whole framework.

Within each goal set, objectives were created to provide more specific categories that measures might fall in. The purpose of these objectives was to summarize a desired result that would contribute to the related goal. Identified measures could then be grouped where applicable, and additional objectives could be added as-needed. Separate objectives were created for internal agency measures and external system measures as found in literature. However, some objectives could be applicable in both areas. Additionally, objectives within the first two goals overlapped significantly, as many applied to both. For example, reducing travel would contribute to a reduction of both pollutants and GHGs.

Identified potential measures were used to create indicators for use in the framework. For the purpose of this research, indicators are similar to performance measures, but without specific measurement requirements or data units. These indicators were then arranged within the initial framework based on subject area. Several additional indicators were created by the research team where any gaps were noted in literature-based indicators. Similar to objectives, many indicators could apply to both the goal of reducing pollutants and the goal of reducing GHGs. Some overlap exists between the agency and system track as well. For example, vehicle age applies to both the emission of pollutants and of greenhouse gases, and can also be tracked for TxDOT vehicles specifically. In addition to goals, objectives, and potential indicators, the initial framework also included potential areas of applicability for each indicator. In some cases, this related to potential modes that could be included in the indicator. The scale of application was also considered—in other words, an indicator might be applicable at a statewide level, a district level, or even a city or corridor level. Appendix E contains a compendium of all indicators that had been identified at this point, along with potential scope for each indicator.

A copy of the revised set of indicators is included in Appendix F for reference. A justification category was then added to provide some basis for indicator inclusion. The way the indicators relate to achievement of the goal was described, and the desired direction was also given. A fourth goal (Reduce environmental effects associated with transportation-related emissions), was initially included as part of the framework, and later discarded. This goal is however still included in Appendix F.

Development of Finalized Framework

The final framework of goals, objectives and indicators was developed based on the preliminary identification of indicators from literature and development of the compendium and broad framework described in the previous section and further detailed in Appendices C through F. As shown in Figure 3, the framework developed contains common goals with different objectives and indicators for the system and agency levels. Researchers conducted several reviews in conjunction with TxDOT before arriving at a final framework. The final goals and system and agency level objectives are shown in Table 4. While there are no direct agency-level objectives under Goal 3, it is to be noted that most agency-level objectives for Goals 1 and 2 still do have an indirect influence on Goal 3 as well.

Table 4: Final Goals and Objectives

Goal	Agency-Level Objective	System-Level Objective
1. Reduce transportation-related pollutant emissions	Improve characteristics of the TxDOT state fleet of vehicles to reduce pollutant emissions	Reduce pollutant emissions from on-road sources by improving operations
	Reduce emissions through projects and efficient funding	Reduce pollutant emissions from on-road sources by improving technology
	Increase employee response to AQ problems	Reduce pollutant emissions from non-road sources by improving operations
2. Reduce transportation-related greenhouse gas (GHG) emissions	Improve characteristics of the TxDOT state fleet of vehicles to reduce GHG emissions and fuel consumption	Reduce pollutant emissions from on-road sources by improving operations
	Reduce emissions through projects and efficient funding	Reduce pollutant emissions from on-road sources by improving technology
	Increase employee response to AQ problems	Reduce pollutant emissions from non-road sources by improving operations
3. Reduce the impact of transportation-related emissions on human health	-	Reduce exposure to poor air quality
		Track changes in national standards

For the system and agency levels, corresponding performance indicators were indentified. These indicators were based on the preliminary compendium of indicators and frameworks indentified as part of this research and shown in Appendices E and F. The final indicators of interest were selected based on the characteristics of good performance measurement, including controllability, relevance, and usefulness. In order to eliminate weaker indicators, the relevance to the agency was considered for each indicator. The amount of agency control over the outcome was considered, as was the overall importance to air quality goals. Some indicators were eliminated if researchers determined that results would likely not be clear or consistent. Indicators that had a relatively small impact on air quality were removed. Indicators that TxDOT had very little control over were similarly removed, as any change would not likely result from or reflect on agency actions. Additionally, some indicators were removed from the framework if researchers believed TxDOT would find no value in them. The potential importance to TxDOT and relevance to TxDOT goals was considered on multiple occasions.

Another significant consideration was measurability. Some potential indicators were eliminated due to concerns over expense and time required, as well as data availability. If an indicator is not practical and realistic, it is likely not very useful to the entity performing the analysis. Most of the remaining indicators had similar temporal scales—updates would likely occur every year, or every several years. On the other hand, a few indicators would likely require more time between updates. Most indicators could be applied at a statewide level, and some could also be applied to a smaller area such as a county or nonattainment area. For a few indicators, however, geographic scale does not apply. After extensive review, the final ideal framework was significantly smaller than previous incarnations, although fewer indicators can make results easier to communicate. In addition, several additional indicators were added based on input from TxDOT.

Many of the identified indicators addressed multiple goals; however, a final set of unique agency-level indicators and system-level indicators was developed. Table 5 summarizes these indicators and which goals they correspond to. Selected indicators from this framework are then quantified and developed into specific performance measures for scoring performance at the agency level (described in Chapter 3) and tracking at the system level (described in Chapter 4). As with the objectives discussed earlier, even though no agency-level indicators directly link to Goal 3, many of the final indicators have an indirect influence on the goal.

Table 5: Final Set of Indicators

Application Level	Indicator	Applies to Goal:		
		1	2	3
Agency	Size of TxDOT fleet per vehicle type	✓	✓	
	Annual TxDOT VMT by classification	✓	✓	
	Average age of TxDOT fleet per vehicle type	✓	✓	
	Percent of TxDOT vehicles that are hybrid or alternative fuel vehicles (AFVs)	✓	✓	
	Fuel used per vehicle type broken into different fuel types (gasoline, diesel, ethanol, propane, biodiesel, CNG, etc.) for TxDOT fleet		✓	
	Average fuel efficiency of TxDOT vehicles by classification		✓	
	Annual engine-hours for desired non-road TxDOT vehicles	✓	✓	
	Air quality impact of environmentally significant projects (i.e. NEPA approved)	✓	✓	
	Usage of allocated CMAQ funds	✓	✓	

	Use and benefits of TERP funds	✓	✓	
	OAD TxDOT employee response	✓	✓	
System	Vehicle-hours of idling by classification	✓	✓	
	Annual VMT by classification by area	✓	✓	
	Vehicle-trips by classification	✓	✓	
	Number of registered vehicles by type	✓	✓	
	Annual freight ton-miles	✓	✓	
	Trips by foot or bicycle	✓	✓	
	Congestion Index	✓	✓	
	Average vehicle age by classification	✓	✓	
	Percent of vehicles passing inspection on first test in non-attainment areas with inspections	✓		
	Gallons of fuel consumed by on-road vehicles, by fuel type (i.e. gasoline, diesel)		✓	
	Annual VMT by mode for desired non-road vehicles	✓	✓	
	Number of days the Air Quality Index (AQI) is in an unhealthful range (values above 100)			✓
	Total population or percent of population living within a certain distance of a freeway			✓
	"At-risk" population living within a certain distance of a freeway as a total or percentage			✓
	Number of schools within a certain distance of a freeway			✓
	Change of fuel efficiency standards by classifications			✓
	Change of emissions standards by classifications			✓

Introduction to Measure Quantification

From among the agency-level indicators identified as part of the framework, the following were selected in conjunction with TxDOT as being the most useful to track:

Air quality impact of environmentally significant projects—difference between baseline and projected emissions associated with new projects that have gone through the entire National Environmental Policy Act (NEPA) process and been approved statewide;

Usage of allocated Congestion Mitigation and Air Quality (CMAQ) funds—how much funding was actually utilized in each nonattainment area compared to how much was available;

Use and benefits of Texas Emissions Reduction Plan (TERP) funds—comparison of dollar amount approved versus applied for, and emissions benefits of funded projects;

Ozone Action Day employee response—survey information to determine TxDOT employee awareness of and response to OADs; and

TxDOT fleet characteristics—could include many aspects of TxDOT vehicles as found in the Equipment Operations System (EOS) Database; fleet size and fuel consumption by vehicle class are illustrated in this chapter.

The quantification of these indicators as specific performance measures are described in this chapter. As measures, the indicators are fully defined with quantification criteria.

Air Quality Impact of Environmentally Significant Projects

This measure will examine projects that go through the entire NEPA process (i.e. a final Environmental Impact Statement (FEIS) is approved and a Record of Decision (ROD) exists). The expected difference of emissions between the baseline ('no-build' scenario) and each project, whether positive or negative, will be investigated, for all approved projects in a given year.

The National Environmental Policy Act (NEPA), signed into law on January 1, 1970, provides a federal-level basis for environmental efforts. The Act "establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment", as well as establishing processes to meet goals and establishing the Council on Environmental Quality (CEQ) to oversee the Act (*57*). NEPA mandates that federal agencies assess expected environmental impacts of major actions and propose alternatives, if applicable. The level of analysis depends on whether or not the activity will affect the environment, and to what degree. Based on criteria already determined by the agency to have no significant impact on the environment, the action may be 'categorically excluded' from detailed analysis. Thus, a project type that has been historically excluded should also be. If the action cannot be categorically excluded, the agency must prepare an environmental assessment (EA) to assess level of environmental impact. A finding of no significant impact (FONSI) is issued if the action would not significantly affect the environment, and may include agency actions to mitigate potential impacts. A more detailed evaluation must be performed if the environmental impact may be significant. An Environmental Impact Statement (EIS) examines both the purpose and environmental consequences of the action, and discusses alternatives. The agency must provide a public record of EIS findings, and how the results were used in decision-making for the action. Additionally, the agency may choose to prepare an EIS without prior preparation of an EA if environmental impacts are already expected to be significant or if a project is 'environmentally controversial' (*57*). Thus, an EA primarily addresses projects for which the impact is relatively unknown.

In addition to significant environmental impacts, TxDOT suggests EIS preparation for projects expected to have significant social or economic impacts (*58*). A 'Purpose and Need' statement is required for both an EA and an EIS, to justify the project or any alternatives. Purpose and need can include categories such as safety, maintenance, system linkage, and instances where demand exceeds capacity. Potential impacts to natural resources must be studied, for both the project and project alternatives. Other analysis can include affects to cultural resources, hazardous material assessment, socioeconomic/environmental justice impacts, existing environment, noise, and air quality. Air quality analysis must be done in both attainment and nonattainment counties, although the analysis is not done for project alternatives. An environmental mitigation plan is also prepared to describe measures to mitigate negative impacts of the project. An EA or EIS draft must be approved by the FHWA for federal-aid projects or the Environmental Affairs Division (ENV) for other projects. Additionally, a public hearing of the draft document must be conducted when required. Final approval is given by the ENV, and by FHWA if the project is federally-funded.

Data Source and Analysis

Data should be available from TxDOT's Environmental Affairs Division (ENV). All EIS documentation statewide for the desired year for projects that underwent full NEPA review and were approved are required for full quantification of the measure. As the measure will be quantified as the difference in emissions between the baseline and the selected project option for all applicable projects, information on emissions for baseline and project option scenarios is needed. Such information should be obtainable from RODs or supplemental air quality tech memos.

Results and Evaluation

In order to evaluate the emissions impact of these projects, some additional investigation may be required. Out of several FEISs, RODs, and AQ tech memos found available online, no consistent method of reporting emission impacts was found. The clearest example was found in an AQ tech memo prepared by WSDOT for a pontoon construction project. Figure 4 illustrates the reporting format used.

EXHIBIT 9
Maximum Annual Emission Comparison in Grays Harbor by Alternative in Tons per Year

Alternative	Oxides of Nitrogen	Carbon Monoxide	Sulfur Dioxide	Volatile Organic Compound	Particulate Matter (PM_{10})	Particulate Matter ($PM_{2.5}$)
No Build	0	0	0	0	0	0
Anderson & Middleton	330	152	53	26	51	32
Aberdeen Log Yard	336	153	52	26	51	32

Figure 4: Example reporting of emissions impact in an EIS (*59*).

With the additional knowledge of what project alternative was selected, such data could be totaled for all applicable projects for the year under consideration, as well as for the No Build alternative reported for each project, as shown in the following equations:

where *i* represents an individual project out of *n* total projects. Each equation would be applied for all pollutants under consideration. Since there are multiple pollutants that are included in this measure, the final result would be best represented in graphical form. Figure 5 below shows an example graphical summary of this measure using the above data, and assuming the first project alternative (Anderson & Middleton) is built.

Figure 5: Example graphical representation of NEPA measure.

For this example, there are significantly more emissions from the project than from the no-build scenario. Hopefully, however, with all actual projects combined together, the emissions impact would be less from the projects than from the no-build option. In summary, the total emissions impact of these NEPA-approved projects, whether positive or negative, would be determined and compared to the impact of not building any of them. However, considerable effort may be required to identify and format the emissions data from each project.

Usage of Allocated CMAQ Funds

This measure examines how much CMAQ funding was available to each NA area, and how much was actually utilized. For this measure, only nonattainment areas are considered since those are the locations funds are allocated to. Since CMAQ projects should contribute to air quality improvement, it is highly desirable that as much of this funding is used as possible.

The Congestion Mitigation and Air Quality (CMAQ) Improvement Program was originally brought into law with the 1990 amendment of the Clean Air Act, and was reauthorized with the Transportation Equity Act for the 21st Century (TEA-21) in 1998 and with the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) in 2005 (*60*). This program provides funding to state DOTs, MPOs, and transit agencies under the joint administration by the FHWA and FTA, although this funding is specifically for nonattainment areas or maintenance areas. Currently, the only pollutants considered when distributing funds are CO and ozone (*61*). County population is also considered when funds are apportioned to different areas. CMAQ encourages environmental consideration within transportation planning, as the program only funds surface transportation and related projects that help improve air quality and reduce congestion. Since funds are limited, planners should attempt to focus on projects that can achieve the greatest emission reduction, and should also consider cost-effectiveness. Typical CMAQ-funded projects in Texas include, for example:

Signal re-timing;

High-occupancy vehicle lanes;

Park-and-ride lots;

Motorist assistance patrols;

Improved transit service;

Fleet conversion to alternate fuels (*62*).

Many projects funded by CMAQ are TCMs. Some project types are ineligible for funds, such as vehicle retirement programs, highway capacity expansion, and highway maintenance. However, funding can be allocated to improving or creating transit programs, as well as providing financial incentive for transit users. Other program areas include traffic flow improvements, pedestrian and bicycle programs, public education and outreach, and inspection and maintenance programs (*63*). Funds have also been used for experimental pilot projects, and diesel engine retrofit programs are encouraged.

State DOTs must provide an annual report detailing emission reductions and project costs for each CMAQ project, listed by project category. In order to obtain funding for a project, a proposal must be submitted with quantitative emissions reduction estimates if possible (although for some project categories, such as public education, only a description of benefits may be all that can be done). To receive final authorization by the FHWA or the FTA, a project must either be included in or be added to the Transportation Improvement Plan (TIP) and most current transportation conformity plan for the entity in question.

Data Source and Analysis

Data for this measure could likely be obtained from STIP and letting information provided by TxDOT Transportation Planning and Programming Division (TPP). As a basic example of a potential result that could be obtained for this measure, researchers investigated FY 2009 data from the Houston-Galveston Area Council (H-GAC) related to Transportation Improvement Program CMAQ and Surface Transportation Program-Metropolitan Mobility (STP-MM) dollar amounts (*64*). The source gave the allocation for CMAQ for FY 2009, as well as the dollar amount of CMAQ projects for FY 2009. In addition, a list of all projects for FY 2009 is included, along with the funding type for each project (CMAQ vs. STP-MM) and the sponsor for the project (i.e. TxDOT Houston District, H-GAC, City of Houston, etc.). Thus, data for just CMAQ-funded TxDOT projects could be identified.

Results and Evaluation

The basic results given by H-GAC provide an example of how this measure could work. Figure 6 below shows the summary tables provided by H-GAC.

Programming Targets/Allocations

Total Dollars	
Funding Category	FY 2009
CMAQ	$ 91,898,000
STP-MM	$ 106,833,000
Grand Total	$ 198,731,000

Projects in FY 2009 (YOE Dollars)

Total Dollars	
Funding Category	FY 2009
CMAQ	$109,049,999
STP-MM	$110,759,328
Grand Total	$219,809,327

Percent Over Programmed

Funding Category	FY 2009
CMAQ	19%
STP-MM	4%
Grand Total	11%

Figure 6: Summary of CMAQ and STP-MM funding for H-GAC for FY 2009 (*64*).

As illustrated, the total amount allocated for CMAQ was less than the cost of all CMAQ projects for FY 2009. Thus, they were 19 percent 'over programmed' for the fiscal year. Summing the project costs for all TxDOT Houston District CMAQ projects yielded a total project cost of $33,587,692. This amount is about 37 percent of the total amount allocated for CMAQ, and about 31 percent of the total cost of all CMAQ projects for FY 2009.

On the other hand, the overall cost of projects versus the overall amount allocated can provide the basis for the measure, as the funds are used to achieve similar goals no matter what agency is using them. In addition, many transportation agencies work with TxDOT significantly. Thus, a final measure could be obtained as shown in the equation below:

This comparison could be done for each separate district, or NA districts, such as the Houston District above.

Use and Benefits of TERP Funds

As these funds directly promote emission reductions, TxDOT should ideally maximize use. Thus, this measure examines the dollar amount of grants approved versus applied for. In addition, the emissions benefits of funded projects will be measured.

The Texas Emission Reduction Plan (TERP) was created in 2001 to help improve air quality across the state, primarily through the use of voluntary financial incentive programs and assistance programs (*65*). Funding to aid in emission reduction is primarily directed toward nonattainment and near-nonattainment areas, as these areas have the largest emission levels, although other affected areas may be included. This allocation would also best address the TERP goal of meeting federal standards and decreasing negative health impacts of polluted air. Other TERP goals include developing solutions that address multiple pollutants, and funding research and development that will benefit both the environment and the economy in the state.

Programs are administered by various state agencies, including TCEQ. Emission Reduction Incentive Grants are awarded to eligible projects to help fund efforts to reduce NOx emissions from high-emitting mobile diesel sources associated with the project. Included in this grant program is the Rebate Grant Program, which helps fund replacement or repowering on-road and nonroad diesel sources. The New Technology Research and Development (NTRD) Program provides funds for the development of pollution reduction technology, and New Technology Implementation Grants (NTIG) are available to help offset implementation costs. The Clean School Bus Program is intended to reduce child exposure to diesel exhaust, and funds projects such as diesel oxidation catalysts and particulate filters. The Heavy-Duty Motor Vehicle Purchase or Lease Incentive Program helps with purchase or lease of new on-road vehicles that meet designated NOx standards if this vehicle is in place of a higher emitting diesel vehicle. A similar program exists for light-duty vehicles, including cars and light trucks. There are also programs to promote energy efficiency, which include aid to counties and other political entities for establishment of energy-efficiency measures.

As these funds directly promote emission reductions, all funds should ideally be used. Thus, this measure examines the dollar amount of grants applied for versus the total amount of grant money that is available for use. In addition, the amount of emissions that were supposed to be saved through funded projects should also be observed in order to understand relative effectiveness of different projects, as well as the total impact of the TERP program.

Data Source and Analysis

Information on TERP grants and funding can likely be provided by the TxDOT General Services Division (GSD). The first part of this measure could be calculated as:

The result would indicate the extent to which TxDOT receives necessary funding for the types of projects supported by the TERP program. In addition, the emissions benefit would be best represented as a sum for each pollutant addressed, as shown in the following equation:

where *i* represents an individual project out of *n* total projects. The result of this equation would indicate the extent of benefits received from TERP-funded projects.

Results and Evaluation

Based on data found online from the TCEQ, the TERP program has granted almost $786 million to date, resulting in about a 158 thousand ton reduction of NOx over the expected life of all funded projects (*66*). However, out of all funded projects to date, only one is a TxDOT project, which seems to indicate that TxDOT can significantly increase application for TERP grants in the future to help reduce emissions. On the other hand, there was no available information on how much grant money TxDOT had applied for but did not receive, if any. The one TxDOT project involved the use of qualifying fuel for an on-road truck in the HGB nonattainment area, resulting in a reduction of about 50 tons of NOx from a grant of $637,637. Ideally, in the future there will be more projects that can be included in this measure.

Ozone Action Day Employee Response

Researchers determined that the best option of observing TxDOT initiatives related to Ozone Action Days (OADs) would be to survey employees about their awareness of and response to Ozone Action Days in nonattainment (NA) and near-nonattainment (NNA) areas. As an example, five potential questions asked of employees could be:

> Do you know what an Ozone Action Day is?
>
> Are you aware of Ozone Action Days when they occur?
>
> What mode of travel do you typically take to work (personal vehicle, carpool, vanpool, bus, other mass transit, bike, walk, or other)?
>
> Of the above modes, how do you travel to work on Ozone Action Days?
>
> Is there anything else you are likely to do in response to an Ozone Action Day (i.e. bring your lunch, etc.)?

Data Source and Analysis

An actual survey of employees would need to be conducted, at least for districts that contain NA or NNA areas and divisions in NA and NNA areas.

Results and Evaluation

In order to evaluate performance, some sort of scorecard would have to be created to translate responses into performance. For example, points could be applied to modes that are considered beneficial, while a 'personal vehicle' response would result in a score of zero for that question. The first two questions would be scored as one or zero, for a yes or no answer, respectively. The same could be done for the last question, although it may be advantageous to also allow open-ended responses to this question. A final 'score' for each participating employee would contribute to the overall evaluation of employee response to OADs.

TxDOT Fleet Characteristics

Many measures could be applied to TxDOT-owned vehicles and equipment. The two measures determined to be the most relevant include:

- The size and modal makeup of the fleet; and
- Fuel consumption of the fleet.

TxDOT has more direct control of the use and makeup of their fleet than of privately owned vehicles; additionally, fuel use for TxDOT fleet can be more easily monitored, and TxDOT has greater ability to adopt special fuels than to get the public to do so.

Data Source and Analysis

The performance measures that relate to the TxDOT vehicle fleet all derive their data from the TxDOT Equipment Operations System (EOS) Database. The databases that researchers had access to were the FY2007 database for on-road vehicles and the FY2008 database for off-road vehicles. Both databases contain a field that lists a classification code (CLASS-CODE) for each vehicle. Based on accompanying field data, the following classification codes were identified for different vehicle types:

- Automobile: 20010 – 25020;
- Bus: 26010;
- Light Truck: 400010 – 490010; and
- Heavy Truck: 500010 – 610000.

Any remaining vehicles were classified as 'other on-road vehicles and equipment', and all nonroad vehicles were grouped together. Additionally, each vehicle record had a field for gasoline, diesel, and other fuels consumed for the year 2007. Although the nonroad database was for 2008, the 2007 data included in that database was used. In order to calculate an average per vehicle rate, the 'count' function was used in Microsoft Excel for each fuel type and vehicle classification to determine the number of cells that were not blank—this value represented the number of vehicles actually using that type of fuel. Similarly, the cells were totaled using the 'sum' function to obtain the total number of gallons of fuel used per fuel type and vehicle class. Then, the average number of gallons used per vehicle using that fuel was computed.

Based on classifications in the database, 'other fuels' appears to include: biodiesel, compressed natural gas (CNG), flex fuel, kerosene, liquefied petroleum gas (LPG) (primarily propane), methanol, and hydrogen.

Results and Evaluation

Figure 7 below illustrates the number of TxDOT vehicles by type.

Figure 7: Size of TxDOT fleet by vehicle classification.

As shown, the largest category of vehicles that TxDOT owns is for light-duty trucks. The number of HDV and nonroad vehicles are similar, but only about half the amount of LDT. On the plus side, LDT may emit less and consume less fuel than heavy duty trucks and on-road or nonroad equipment. Although TxDOT owns almost 500 passenger cars, that amount is relatively small compared to the other vehicles and equipment. Based on the records in the database, the category for 'other on-road vehicles' includes:

Aerial personnel devices;

Asphalt booster tanks;

Asphalt distributors;

Asphalt maintenance units;

Asphalt pothole patchers;

Core drills;

Earth boring machines;

Cranes;

Mixers;

Paint stripe machines;

Platform lifts;

Sprayers (herbicide/insecticide);

Storm and drain pipe cleaning;

Sweepers; and

Tanks (fuel, storage, water, etc.).

The average fuel consumption per in-use vehicle is shown in Figure 8.

Figure 8: Fuel consumption of TxDOT fleet by vehicle classification.

CHAPTER 4: QUANTIFICATION OF SELECTED SYSTEM-LEVEL AIR QUALITY PERFORMANCE MEASURES

Introduction to Measure Quantification

Based on the system-level indicators identified in the framework in Chapter 2, nine performance measures are further defined and quantified based on currently available data to show how these can be tracked over time as general indicators of air quality. These measures include:

Annual VMT by vehicle classification and area;

Annual freight ton-miles by vehicle classification;

Average vehicle age by classification;

Percent of vehicles passing inspection on first test in nonattainment areas with inspections;

Number of days the air quality index (AQI) is in an unhealthful range (values above 100);

Population living with 1.5 miles of a freeway in nonattainment areas;

Number of schools within a certain distance of a freeway in nonattainment areas;

Changes in vehicle fuel efficiency standards; and

Changes in vehicle emissions standards.

Through this set of measures, all three air quality goals are represented, as well as different aspects of these goals. The first three measures apply to both Goal 1 and Goal 2, as both pollutant and GHG emissions are affected. These measures were also determined to be some of the most robust and interesting. Some measures were not included because the quality of available data was not sufficient enough to provide a useful measure. Additionally, the congestion index was not investigated, as TxDOT already tracks this measure through the TxDOT Tracker.

In terms of spatial scale, several measures were evaluated for nonattainment areas, in addition to state totals. Depending on the measure, data might be averaged or summed over all the counties included in the nonattainment area. Additionally, these measures were then evaluated for all nonattainment areas as a whole.

Measure 1: Annual Vehicle-Miles Traveled

Examination of vehicle-miles of travel is important, as fuel consumption and emissions levels tie very closely to the amount of VMT. Modal split along with VMT data is also very relevant, as heavier vehicle classes such as large trucks tend to emit more and use more fuel per mile of travel. VMT is also a good overall measure of total transportation system use.

Data Source and Analysis

Data for this measure involved Highway Performance Monitoring System Data (HPMS) allocated to vehicle categories using TxDOT classification counts and MOBILE6 defaults developed by the Texas Transportation Institute (TTI). Historical miles of travel from 1990 to 2008 was available on a per-county basis. Additionally, approximate modal split in each district for light duty vehicles (LDV), light duty trucks (LDT), heavy duty vehicles (HDV), and heavy duty vehicles with a gross vehicle weight rating (GVWR) greater than 60,000 lbs (HDV8b) was given. A list of the district associated with each county was supplied as well. Using the 'vlookup' function in Microsoft Excel, appropriate modal percentages were applied to the VMT for each county. After summing the VMT for each mode for a state total, the modal split across the state as a whole could be obtained. Analysis was also conducted for each nonattainment area.

Results and Evaluation

Figure 9 below shows the annual VMT for separate NA areas, all NA areas combined, and the state as a whole from 1990 to 2008.

Figure 9: Historical VMT for Texas and NA Areas.

As shown, VMT has increased at a fairly steady rate for all areas, including BPA and EP, although these trends cannot be discerned as well from the graph due to the scale. Overall, VMT for Texas as a whole has increased by nearly 100 billion miles travelled per year over a span of almost two decades. However, there was a decrease in VMT between 2007 and 2008 for all areas, although more significant for some. This decrease is likely related to gas prices, although additional years of data will contribute to a better understanding of this trend. In addition, Figure 10 shows the basic mode shares represented in this data set for each area for 2008. Although the larger areas experienced some change in modal split since 1990, this change was very slight. Thus, only the most recent data is illustrated.

Figure 10: 2008 Mode Split of VMT for Texas and NA Areas.

As shown, LDV and LDT account for approximately 60 and 30 percent of VMT, respectively, while HDV8b account for slightly more of the remaining VMT than HDV. However, researchers did find the modal split for the BPA area to be rather interesting. LDV contributed significantly less to VMT in the area compared to all other areas, while significantly more VMT came from trucks of all types. In fact, the percentage of VMT from HDV8b was about twice as much in BPA than in other NA areas and the state as a whole. HGB also had more LDT travel than other areas (other than BPA), but the percentage of truck travel, light and heavy, was typically less in NA areas than the state as a whole. This finding is somewhat interesting, since trucks typically contribute more to emissions than LDV.

Measure 2: Annual Freight Ton-Miles

Freight ton-miles are similarly significant. As more travel occurs, more fuel is consumed, and more pollutants and GHGs are emitted. However, ton-miles are also important since they provide an idea of the actual weight that is transported. Heavier loads may cause increased pollutant and GHG emissions, as well as increased fuel consumption. Since freight is carried on different modes, it would be desirable to observe an increased mode share for lower emitters.

Data Source and Analysis

Data for this measure was obtained from Commodity Flow Surveys available online through the U.S. Bureau of Transportation Statistics (BTS). All available online reports were used in order to identify any historic trends (*67-70*). These reports cover 1993, 1997, 2002, and 2007, and the BTS currently publishes this report every five years. Data is available for each state, and includes different shipment modes as well—both single and multiple shipments. Multiple shipments include several modes, such as both truck and rail, for each freight movement. However, this data is likely less reliable than data for single modes. A significant increase occurs for several multiple mode categories in 2007, but such a large change may be due to increased monitoring or reporting.

Results and Evaluation

From the given data set, freight ton-miles for the major single modes was selected as the most interesting data set. The trend from 1993 to 2007 is shown in Figure 11.

Figure 11: Freight ton-miles for single modes.

For shipment by air, the total number of ton-miles ranges from 197 million to 323 million, although the increase is not noticeable in the figure. Ton-miles by water have decreased significantly, while the ton-miles by truck have increased at an even greater rate. Interestingly, ton-miles for freight have alternated between decreasing and increasing. On the other hand, this only presents a general trend since there is a four or five year gap between each data point.

Measure 3: Average Vehicle Age

This measure reflects the average vehicle age by vehicle class, based on 2010 registration data. Vehicle age affects both pollutant emissions and GHG emissions, as older vehicles typically emit more pollutants and consume more fuel per unit of distance. Thus, a decrease in average vehicle age (i.e. vehicles are newer) would be desired.

Data Source and Analysis
Data for this measure involved HPMS allocated to vehicle categories using TxDOT classification counts and MOBILE6 defaults developed by TTI. This data set included vehicle categories for passenger cars, motorcycles, trucks less than 6,000 lbs GVWR, trucks between 6,000 and 8,500 lbs GVWR, and both gas and diesel trucks with a GVWR over 8,500 lbs. Within each classification, the number of vehicles were given for vehicle model years of 2009 to 1980, with an additional category for vehicles older than 1980. This data was further broken down for each county in Texas, and included a state total as well.

Rather than give vehicle age in terms of model year, age was given as the number of years prior to 2010. For example, a vehicle made in 2007 would be considered three years old. In order to compute the average age, vehicles made prior to 1980 were assumed to be 35 years old. The average age for each vehicle class could be computed for different geographical scales: each nonattainment area, all nonattainment areas together, and state total. Since the number of vehicles of each age was given, the average age is essentially a weighted average, computed for each vehicle class as:

where *i* is the vehicle age (thus, 35 comes from the assumed vehicle age of vehicle made prior to 1980).

Results and Evaluation
The average age for each vehicle class and analyzed area is illustrated below in Figure 12. Although data existed for gas trucks with a GVWR over 8500 lbs, this was not included due to their relatively small presence in the overall fleet.

Figure 12: Average vehicle age by classification by area.

Several observations can be made from the above figure. Interestingly, the average vehicle age in nonattainment areas is typically less than the state average. On the other hand, the oldest vehicles appear to be located in El Paso, which likely contributes to the nonattainment status there for particulate matter. Trucks less than 6,000 lbs GVWR and gas trucks greater than 8,500 lbs GVWR are the oldest vehicles on average, especially in El Paso. Trucks between 6,000 and 8,500 lbs GVWR are the newest trucks on average for each geographical scale.

Measure4: Vehicles Passing Emissions Test on First Inspection

The actual emissions rates of individual vehicles make up the total emissions across the state. It is desirable that as many vehicles as possible conform to emission standards. This measure provides a method to examine how many vehicles are within accepted standards, as well as improvements in the vehicle fleet over time.

Data Source and Analysis

An extensive review of the Texas Inspection and Maintenance (I/M) program for the 2004-2005 and 2007-2008 biennials was conducted by Eastern Research Group (ERG) for TCEQ (*71*, *72*). These reports include participation, inspection, and repair statistics associated with the program. Inspections currently occur only in the DFW and HGB nonattainment areas. Data on the number of vehicles with different pass/fail patterns was used. Additionally, only data with a certified final test and either a verified initial test or an initial test that could be assumed as a true initial test was used. Approximately 99.3 percent of test sequences in 2006 and 99.98 percent in 2009 met these criteria (*72*). Since part of this data set was for both DFW and HGB together, the analysis was conducted for the program as a whole. The percent of test sequences that began with a pass were summed together to obtain a final rate.

Results and Evaluation

Summarized data for all verified test sequences in each report is presented below in Table 6, which also includes final rates for the percent passing on the first test.

Table 6: Vehicles Passing Emissions Test on First Inspection

Test Sequence	2004-2005			2007-2008		
	Vehicle Frequency	% of Vehicles	**Percent Initially Passing**	Vehicle Frequency	% of Vehicles	**Percent Initially Passing**
P	13,505,302	93.939	**94.160**	14,586,693	95.165	**95.400**
PP	30,371	0.211		34,786	0.227	
PPP	137	0.001		228	0.001	
PFP	1,218	0.008		1,078	0.007	
FP	789,851	5.494		674,341	4.399	
FFP	43,733	0.304		27,556	0.180	
FFFP	2,607	0.018		1,412	0.009	
FF	1,107	0.008		707	0.005	
FPP	463	0.003		369	0.002	
FFF	286	0.002		196	0.001	
FFFFP	132	0.001		53	0.000	
F	1,075	0.007		0	0.000	
Other Test Sequences	319	0.002		385	0.003	
Total	14,376,601	100		15,327,804	100	

As shown in the table above, the percent of vehicles passing on the first test increased from 94.16 percent to 95.4 percent between the 2006 and 2009 reports. The vast majority of these vehicles passed the first test and did not get tested again (this amount also increased). It is unclear why some vehicles got retested after passing initially, although one explanation offered by ERG is that the vehicle may have failed its first safety inspection, and was tested again at a separate facility for both safety and emissions. The second most common test sequence was failing the first test and passing the second. Although it is good that the initial passing rate increased, part of the increase could be due to vehicles that were repaired after failing initially in the 2004-2005 biennial. However, a rate that approaches 100 percent is desirable.

Measure 5: Days with Air Quality Index in Unhealthful Range

The Air Quality Index (AQI) was created by the EPA, and used by all 50 states, as a way to present pollutants in a clear index so that the health impacts of concentrations could be easily communicated. The AQI applies to ground-level ozone, particle pollution, CO, SO_2, and NO_2. The index is calculate with different equations for each pollutant, and the highest value is reported along with the responsible pollutant. The EPA requires metropolitan areas with populations greater than 350,000 people to report the AQI to the public daily (*73*). AQI values correspond to a color and associated level of health risk, for easy interpretation. Figure 13 illustrates the health risks that pertain to different AQI levels.

Air Quality Index Levels of Health Concern	Numerical Value	Meaning
Good	0 to 50	Air quality is considered satisfactory, and air pollution poses little or no risk
Moderate	51 to 100	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
Unhealthy	151 to 200	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	201 to 300	Health alert: everyone may experience more serious health effects
Hazardous	301 to 500	Health warnings of emergency conditions. The entire population is more likely to be affected.

Figure 13: AQI ranges and associated health risks (*74*).

Through the use of online calculator tools, it was determined that an AQI value of 100 approximately corresponded to NAAQS for the given pollutants, although some concentrations were slightly greater for an AQI value of 100. However, and AQI value over 100 was determined to be a good indicator of exceedance of national standards.

Data Source and Analysis

Data was obtained online from the American Lung Association, which presents yearly reports on the number of orange, red, and purple days for each state and each pollutant has days over an AQI of 100 (*75*). Data is only available for counties with monitoring capabilities—thus, only 16 counties in nonattainment and 17 other counties are presented as part of this measure. For Texas, the pollutants of concern are ozone and particles. Only some of the thirty three counties monitored both ozone and particles, however, and more monitored ozone than particles. Total counts, basic averages per county, and weighted averages based on population were calculated for currently available 2009 data for the counties that monitor each pollutant. Population data was described as a 2008 estimate.

Results and Evaluation

Figure 14 illustrates the weighted average number of days the AQI was above 100 for all counties available, nonattainment counties only, and other counties (weighted by county population).

Figure 14: Number of days the AQI is in an unhealthful range.

As illustrated in the figure, particle pollution is currently much less of a threat than ground-level ozone, with fewer unhealthy days, and no days classified as 'red' or 'purple'. For ozone, the entire general public in affected areas is at risk—for red and purple days, it is not just 'at-risk' groups that may experience negative side effects. Additionally, there were no red or purple days in counties not classified as nonattainment. Nonattainment areas also experiences a much greater share of orange classification days. Thus, the worst problems seem to be concentrated primarily in nonattainment areas.

It is desirable that there would be fewer high AQI days each year. However, when tracking this measure over time, consideration must be given to any addition of monitoring systems. For example, the total number of high AQI days may increase if more counties begin monitoring and reporting their air quality, even if the air quality is actually improving. Thus, a weighted average, as shown above, may be a better indicator over time.

Measure 6: Population Living Near a Freeway

Research suggests that living near a freeway can significantly increase exposure to pollutants. For example, the South Coast Air Quality Management District suggests that housing not be allowed closer than 500 feet from a freeway (*76*). Increased exposure to particulate matter is one major concern. Based on two studies conducted at the University of California, Los Angeles, (UCLA) "people who live, work, or travel within 165 feet downwind of a major freeway" may be exposed to up to 30 times the concentration of normal particle concentrations further away (*77*). Another study performed by researchers at UCLA, the University of Southern California (USC), and the California Air Resources Board (CARB) suggests that negative effects can extend as far as 1.5 miles downwind (*78*). Additionally, children and the elderly are more susceptible to affects of most pollutants.

Data Source and Analysis

This performance measure was evaluated using a student version of the software ArcGIS, which is a GIS (geographic information system) program. The basic shapefiles for the state and counties came as practice data a student handbook (*79*). This data set also included census data from the 2000 census. Census block files for each county were downloaded, as well as the census block demographic table, from the Census 2000 TIGER/Line data through the ESRI website (*80*). Additionally, roadway line files were obtained through the Texas Natural Resource Information System, or TNRIS, for counties in nonattainment areas (*81*).

Buffers were created around major roadways in each nonattainment areas at 250 ft from the centerline, 500 feet, and 1.5 miles. However, for this population data, the 1.5 mile buffer was determined to be the only one with useful data, and the smaller buffers were too small to contain many census blocks. The number of people in each buffer is also approximate, because census blocks were selected if the centroid fell within the buffer. However, for the 1.5 mile buffer, the area approximately evens out between blocks that were or were not included, as shown in Figure 15 below.

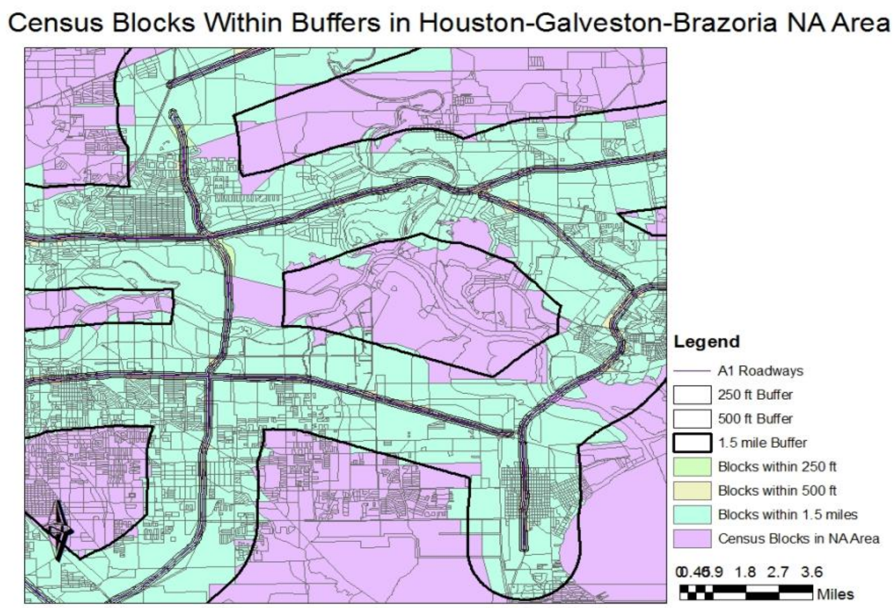

Figure 15: Example of freeway buffers and census blocks in ArcGIS.

Roadways considered had Framework Classification Codes (FCC) beginning with 'A1'—these include primarily limited access freeways and highways. A map showing 1.5 mile buffers around all of the selected roadways is available in Appendix G for each nonattainment area.

Results and Evaluation

Table 7 shows the percent of the total population living with 1.5 miles of the freeway in each nonattainment area, as well as the percent children 17 and under and of the elderly (65 and older).

Table 7: Population Living Within 1.5 Miles of a Freeway

Percent of Population Living Within 1.5 Miles of a Freeway			
Nonattainment Area	Total Population	Population Under 18 Years	Population 65 Years and Over

Beaumont-Port Arthur	37.69%	38.63%	41.64%
Dallas-Fort Worth	60.45%	57.75%	62.18%
El Paso	66.09%	64.22%	76.24%
Houston-Galveston-Brazoria	55.23%	54.10%	55.87%
Average of All Areas	57.73%	55.98%	59.43%

As shown in the table, a significant portion of the population lives within 1.5 miles of a major freeway in nonattainment areas. The situation is worst in El Paso, and percentages are relatively much smaller in BPA. There were also fewer freeways in the BPA area. The portions are also worst for the elderly; and, children are generally somewhat better off than the total population.

Measure 7: Schools Located Near a Freeway

Living or attending school so near to a freeway has also been linked to increased risk of pediatric asthma and stunted lung growth (*82*). Similarly to the previous performance measure, the location of schools to major freeways was examined.

Data Source and Analysis

Data sources and analysis were similar to the last measure, with the addition of school GIS data that provided the geographic location of all schools in Texas, although only nonattainment areas were examined for this measure as well. This point file came from the Texas Education Agency (TEA) (*83*). The same roadways were used, and schools that fell within each buffer were noted.

Results and Evaluation

Figure 16 shows an example of the output for the DFW area.

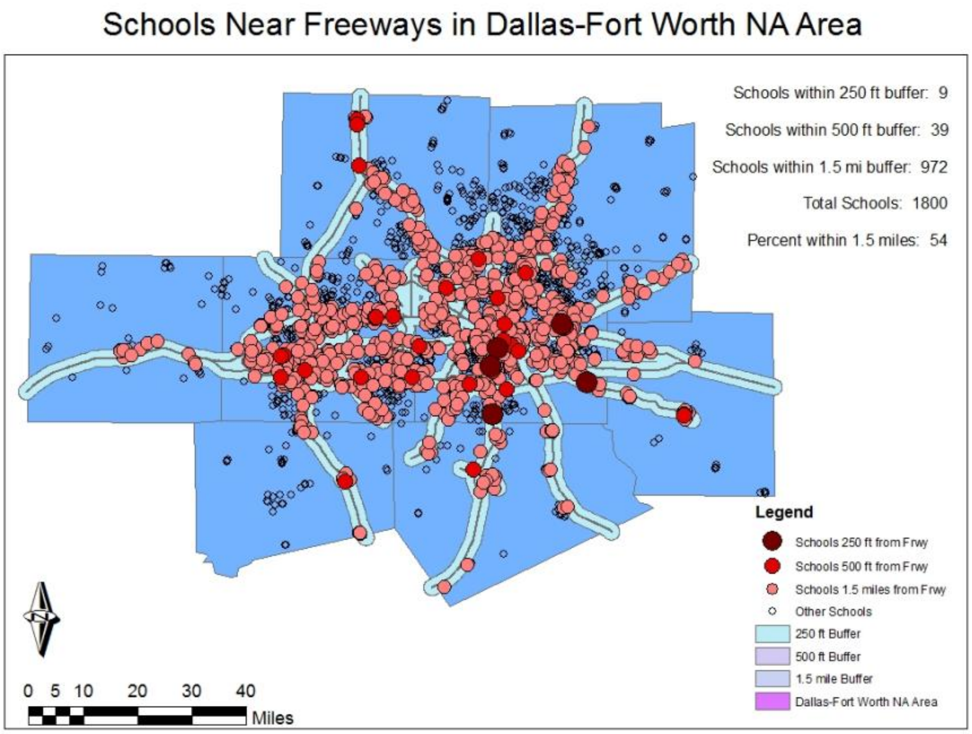

Figure 16: Example of schools near freeways in ArcGIS.

Similar maps for the other nonattainment areas are located in Appendix G. The results of the analysis are summarized in Table 8.

Table 8: Schools Near Major Freeways

Number of Schools Near the Freeway					
Nonattainment Area	Within 250 feet	Within 500 feet	Within 1.5 miles	Total Number of Schools	Percent within 1.5 miles
Beaumont-Port Arthur	1	2	62	135	45.93%
Dallas-Fort Worth	9	39	972	1800	54.00%
El Paso	4	8	160	235	68.09%
Houston-Galveston-Brazoria	12	44	806	1489	54.13%
Total for All Areas	26	93	2000	3659	54.66%

As shown, over half of schools are located within 1.5 miles of a freeway in all nonattainment areas except BPA. Again, situation appears worst in El Paso. In addition, although the percents within 250 feet and 500 feet of the centerline are very small, that is also a very small distance between a school and a major freeway.

Measure 8: Changes in Vehicle Fuel Efficiency Standards

Fuel efficiency standards ensure that vehicle manufacturers make their new vehicles with acceptable fuel economy, in order to better control fuel consumption and emissions. Historically, the fuel efficiency of new vehicles has improved immensely, thanks to standards and technological innovation. Monitoring changes in fuel efficiency standards can help determine the potential fuel economy of vehicles given an age, and can provide insight into future improvements that should be added into air quality considerations and modeling.

Data Source and Analysis

The historic data for vehicle fuel efficiency standards for passenger vehicles and light trucks was obtained from a report published by the National Highway Traffic Safety Administration (NHTSA), which is part of the U.S. DOT (*84*). The data obtained is for the Corporate Average Fuel Economy (CAFE) standards.

Results and Evaluation

Changes in the CAFE standards are shown below in Figure 17. Additionally, a line is projected into the future to represent the expected increase of the passenger car standard by 2020.

Figure 17: Changes in vehicle fuel efficiency standards.

As shown, the fuel efficiency standards have increased significantly since 1978, although there were a few periods of decrease, and the standard for passenger cars has not changed since 1990. However, this standard is expected to be 35 miles per gallon by 2020. In addition, the standards are not as stringent for light trucks—this makes sense since trucks require more fuel. It also appears that the standard was originally for trucks divided between two wheel drive and four wheel drive, but has been combined for some time.

Measure 9: Change in Vehicle Emission Standards

The change in vehicle emission standards is also useful to track. The measure can contribute to interpretation of the emissions inspection measures—For example, if a standard increased significantly, the amount of vehicles passing on the first test may decrease. Additionally, the knowledge should be useful for modeling and prediction emissions.

Data Source and Analysis

Information regarding emission standards is available on the EPA website (*85*). While standards for heavy duty trucks and buses appear fairly straight-forward, standards for LDT and LDV were more complicated. Tier 0 and Tier 1 standards were available for these vehicles for 1981-1993 and 1994-1999 respectively. After that, standards varied, with multiple levels of stringency. For the purpose of this measure, the least severe standards were used for LDT and LDV, as this represents the worst level of emissions allowable per vehicle. Standards for different 'useful lives' exist as well for these vehicles.

Results and Evaluation

Figures 18 and 19 show the standards for heavy duty vehicles and buses.

Figure 18: Emission standards for HDV with compression-ignition engines.

Figure 19: Emission standards for HDV with spark-ignition engines.

These figures show that standards have gotten stricter over the years, as the concentration that can be emitted decreases. Standards for HC and PM allow the smallest concentrations, while standards for CO allow the greatest concentration. A table with values used for Heavy-Duty Vehicles is located in Appendix

Similarly, Figures 20, 21, and 22 show standards for light duty vehicles and two classes of light duty trucks. These figures represent the least strict set of standards.

Figure 20: Emission standards for light duty vehicles.

Figure 21: Emission standards for light duty trucks (up to 6,000 lbs GVWR).

Figure 22: Emission standards for light duty trucks (6,001-8,500 lbs GVWR).

As for HDV, the standards for CO allow the largest concentration, although the concentrations are measured in grams per mile rather than grams per brake horsepower-hour, as for heavy vehicles. Additionally, the standards are stricter for vehicles with 5 years of useful life compared with vehicles that have 10 years of useful life.

CHAPTER 5: FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This task involved an extensive review of applicable literature, as well as an investigation of practices in place among other state DOTs. Current DOT practices were obtained from documents available through DOT websites and reviewed to identify applicable performance measures. In addition to contributing to background information on air quality, emissions, and performance measurement, findings were used in the development of emissions-related performance measures for use by TxDOT.

The following are some concluding remarks:

> Transportation is a major contributor to air pollution in the United States. Between health and environmental consequences of pollutants, and climate change attributed to GHG emission, air pollution is a significant problem. Although EPA only currently considers six criteria pollutants in determination of nonattainment status, other emissions such as MSATs and GHGs will likely receive increasing attention in the future.
>
> The use of performance measurement for emissions and AQ goals is relevant, as it allows an agency to determine progress, if any, in achieving goals. Performance measurement is also useful in decision-making and reporting to stakeholders. Including AQ consideration in decision-making could help ensure that AQ is not sacrificed to mobility and other typical transportation goals.
>
> In developing a PM framework, the relation between goals, objectives, and measures or indicators must be considered. In addition, aspects of ‘good’ measures must be considered, such as measurability, clarity, controllability, and relevance.
>
> Many state DOTs did not have any performance measures, and of the ones that did, few had any that were even generally environmentally related. However, some state DOTs did provide significant guidance when identifying AQ-related measures. Potential measures were also identified in literature and by TTI researchers. For example, tracking actual emissions levels was a measure suggested by most sources.
>
> From TxDOT’s perspective, the AQ performance can be tracked in two ways – one that looks at internal agency actions, and another that looks at system performance. Agency-specific measures are useful, as TxDOT has more direct control over related outcomes. TxDOT is also likely to have access to fairly robust data related to these measures. On the other hand, while TxDOT has less control over system performance, system-wide measures can help provide information related to the overall affect of transportation on air quality in Texas.
>
> Although the final set of agency-level measures focuses primarily on emission ‘source’ goals, both the agency-level measures and the system-level measures were developed with the same overall goals in mind. After much revision, the final measurement framework focused on the following goals:

Reduce transportation-related pollutant emissions (‘source’ goal);

Reduce transportation-related GHG emissions (‘source’ goal); and

Reduce the impact of transportation-related emissions on human health (‘receptor’ goal).

The tracking measures for TxDOT set up an evaluation system that can be updated and tracked based on a set of indicators for performance in non-attainment areas, as well as statewide. This set of measures specifically addresses agency initiatives and programs, including employee actions. The final evaluated measures include:

Air quality impacts of environmentally significant (NEPA) projects;

Usage of allocated CMAQ funds;

Use and benefits of TERP funds;

OAD employee response; and

TxDOT fleet characteristics.

Indicators of system-wide performance can also be tracked and linked to air quality goals. Although TxDOT does not have direct control over all system-level outcomes, the transportation system is the focus of the agency. Thus, knowledge of the performance of the system is invaluable. System-level measures evaluated for this project include:

1. Annual VMT by vehicle classification and area;
2. Annual freight ton-miles by vehicle classification;
3. Average vehicle age by classification;
4. Percent of vehicles passing inspection on first test in nonattainment areas with inspection programs;
5. Number of days the air quality index (AQI) is in an unhealthful range (values above 100);
6. Population living with 1.5 miles of a freeway in nonattainment areas;
7. Number of schools within a certain distance of a freeway in nonattainment areas;
8. Changes in vehicle fuel efficiency standards; and
9. Changes in vehicle emissions standards.

It is useful for an agency to be aware of both the agency-controlled issues and broader system impacts as a whole in order to comprehensively address air quality goals through performance measurement.

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APPENDIX A: LIST OF ACRONYMS AND ABBREVIATIONS

AFV—Alternative Fuel Vehicle

AQ—Air Quality

AQI—Air Quality Index

AVI—Automatic Vehicle Identification

BPA—Beaumont-Port Arthur Nonattainment Area

BTS—Bureau of Transportation Statistics

CAA—Clean Air Act

CAFE—Corporate Average Fuel Economy

CAP—Clean Air Plan

CARB—California Air Resources Board

CEQ—Council on Environmental Quality

CFC—Chlorofluorocarbon

CMAQ—Congestion Mitigation and Air Quality Improvement Program

CNG—Compressed Natural Gas

CO—Carbon Monoxide

CO_2—Carbon Dioxide

DCAT—Drive Clean Across Texas

DelDOT—Delaware DOT

DFW—Dallas-Fort Worth Nonattainment Area

DOT—Department of Transportation

DPM—Diesel Particulate Matter

EA—Environmental Assessment

EAC—Early Action Compact

EIS—Environmental Impact Statement

EOS—Equipment Operations System

ENV—Environmental Affairs Division

EP—El Paso Nonattainment Area

EPA—Environmental Protection Agency

ERG—Eastern Research Group

ESRI—Environmental Systems Research Institute, Inc.

FCC—Framework Classification Code

FHWA—Federal Highway Administration

FONSI—Finding Of No Significant Impact

FTA—Federal Transit Administration

GAO—General Accounting Office

GHG—Greenhouse Gas

GIS—Geographic Information System

GPS—Global Positioning System

GSD—General Services Division

GVWR—Gross Vehicle Weight Rating

HC—Hydrocarbon

HDV—Heavy Duty Vehicle

HDV8b—Heavy Duty Vehicle with a GVWR over 60,000 pounds

HGB—Houston-Galveston-Brazoria Nonattainment Area

HPMS—Highway Performance Monitoring System

I/M—Inspection and Maintenance

ISTEA—Intermodal Surface Transportation Efficiency Act (1991)

ITS—Intelligent Transportation Systems

LDT—Light Duty Truck

LDV—Light Duty Vehicle

LED—Light-Emitting Diode

LPG—Liquified Petroleum Gas

MOVES—MOtor Vehicle Emission Simulator

MPO—Metropolitan Planning Organization

MSAT—Mobile Source Air Toxic

NA—Nonattainment

NAAQS—National Ambient Air Quality Standards

NCHRP—National Cooperative Highway Research Program

NEPA—National Environmental Policy Act

NHTSA—National Highway Traffic Safety Administration

NNA—Near Nonattainment

NO—Nitric Oxide

NO_2—Nitrogen Dioxide

NOx—Nitrogen Oxides

NTE—Not-To-Exceed

NTIG—New Technology Implementation Grant

NTRD—New Technology Research and Development

O_2—Oxygen Gas (Dioxygen)

O_3—Ozone

OAD—Ozone Action Day

OTAQ—Office of Transportation and Air Quality (EPA)

Pb—Lead

PEMS—Portable Emissions Measurement System

pH—Potentiometric Hydrogen Ion Concentration

PM—Particulate Matter

$PM_{2.5}$—"fine" particles with diameters less than or equal to 2.5 micrometers

PM_{10}—particles with diameters less than or equal to 10 micrometers and greater than 2.5

PM—Performance Measurement

ppb—parts per billion

RFG—Reformulated Gasoline

ROW—Right-Of-Way

RVP—Reid Vapor Pressure

SAFETEA-LU—Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

SIP—State Implementation Plan

SO_2—Sulfur Dioxide

SOx—Sulfur Oxides

STP-MM—Surface Transportation Program-Metropolitan Mobility

TCEQ—Texas Commission on Environmental Quality

TCF—Texas Clean Fleet

TCM—Transportation Control Measure

TEA—Texas Education Agency

TEA-21—Transportation Equity Act for the 21st Century

TERM—Transportation Emission Reduction Measure

TERP—Texas Emission Reduction Plan

TIP—Transportation Improvement Program

TNRIS—Texas Natural Resource Information System

TPP—Transportation Planning and Programming Division (TxDOT)

TTI—Texas Transportation Institute

TxDOT—Texas Department of Transportation

UCLA—University of California, Los Angeles

USC—University of Southern California

VMEP—Voluntary Mobile Emissions Reduction Program

VMT—Vehicle Miles Traveled

VOC—Volatile Organic Compound

VSP—Vehicle Specific Power

APPENDIX B: EFFECTS AND OUTCOMES OF COMMON AIR POLLUTANTS

Effects of Common Air Pollutants from Transportation			
Pollutant	**General Information**	**Health Effects**	**Environmental Effects**
Carbon monoxide (CO) A colorless, odorless gas; also poisonous'	Formed when carbon in fuel is not completely burned—about 56% comes from motor vehicle emissions (may be up to 85-95% in cities) and 22% from non-road engines Highest levels typically occur in the colder months Transportation accounts for 70-90% of CO emissions	Reduces oxygen delivery to organs and tissues in the body Can cause vision problems, reduce ability to work or learn, reduce manual dexterity, and difficulty performing complex tasks. High levels can cause death. The health threat is more severe for people who suffer from heart disease. 0.5% in the air can prove fatal in less than 30 minutes by asphyxiation.	Contributes to formation of smog ground level ozone as a catalyst

Ozone (O_3) A pale blue gas composed of three oxygen atoms' [2]	"Good ozone" protects earth from the sun. It is formed naturally about 10-30 miles above the surface in the stratosphere through ultraviolet radiation. It is essential—a 5% drop in concentration could cause 10% more skin cancer and eye cataracts. "Bad ozone" occurs at ground-level, and is created by a chemical reaction between NOx and VOC in sunlight, especially in the summer and urban areas. It can also be carried hundreds of miles in the wind.	At particular risk are children, the elderly, people with lung disease, and people who are active. Ozone causes airway irritation, coughing, pain when breathing, congestion, wheezing and difficulty breathing during exercise or outdoor activities, inflammation (like a sunburn on the skin), aggravation of asthma, bronchitis, and emphysema, increased susceptibility to respiratory illnesses, and permanent lung damage with repeat exposure.	Interferes with the ability of sensitive plants to produce and store food Damages the leaves of trees and other plants, which negatively impacts their appearance Reduces forest growth and crop yield, potentially impacting species diversity in ecosystems Degrades structures (metal and concrete) through oxidation

Lead (Pb) A naturally occurring metal, but extremely poisonous' [2]	Emissions of lead from motor vehicles has declined 95% from 1980 to 1999 due to EPA regulations (levels of lead in the air decreased 94%)	Blood distributes lead throughout the body; it accumulates in the bones and can affect the oxygen carrying capacity of blood, causing anemia Can affect the nervous system, metabolism, kidney function, immune system, reproductive and developmental systems, and cardiovascular system depending on exposure level May cause behavioral problems, learning deficits, and lower IQ in infants and young children, even at lower levels	Accumulates in soils and sediments, and can be transported in the atmosphere. Loss in biodiversity, changes in community composition, decreased growth and reproductive rates in plants and animals, and neurological effects in vertebrates
Nitrogen dioxide (NO_2) One form of NOx, a brown odorless gas' [2]	Transportation accounts for 45-50% of NOx Control measures that reduce NO_2 typically reduce other types of gaseous NOx Near roadway measures can be 30-100% higher than concentration away from roadway, and in-vehicle concentration can be 2-3 times higher	Short-term exposure (30 minutes to24 hours) linked to adverse respiratory effects, including airway inflammation, and eye irritation People with asthma, children, and the elderly are particularly susceptible	Can prevent the growth of crops and reduce agricultural yields Are a catalyst for ozone, and a component of smog and acid rain

Particulate matter (PM) A mixture of tiny particles and liquid droplets, [2]		‘Primary particles’ are directly emitted and ‘secondary particles’ are created by chemical reactions in the atmosphere. They are made up of many things, including acids, organic chemicals, metals, and soil/dust particles. ‘Inhalable course particles’ are between 2.5 and 10 micrometers in diameter, and ‘fine particles’ are less than 2.5. Transportation accounts for about 25% of PM	The smaller the particle, the more dangerous because they can get deeper into your longs, and potentially the bloodstream. Most susceptible are children, the elderly, and people with heart or lung disease. PM is linked to increased respiratory symptoms, decreased lung function, aggravated asthma, development of chronic bronchitis, irregular heartbeat, nonfatal heart attacks, and premature death in people with heart or lung disease. Also a carcinogen.	Visibility reduction—$PM_{2.5}$ is a component of haze Environmental damage—includes making lakes and streams acidic, changing the nutrient balance in coastal waters and large river basins, depleting nutrients in soil, damaging sensitive forests and farm crops, and affecting diversity of ecosystems. Also, PM can travel long distances carried by the wind. Aesthetic damage—can stain/damage stone and other materials, which includes objects like statues and monuments

Sulfur dioxide (SO_2) A heavy colorless gas with a strong odor, one form of sulfur oxide (SOx)[, 2]	Transportation accounts for about 5% of emissions, but related industries like petrochemical are high emitters Control measures that reduce SO_2 typically reduce other types of gaseous SOx	Short-term exposure (5 minutes to 24 hours) linked to adverse respiratory effects like bronchoconstriction and increased asthma symptoms, and eye irritation Children, the elderly, and asthmatics are particularly susceptible (asthmatics especially at elevated breathing like when exercising)	Can inhibit plant physiology, and a component of acid rain Has a counter effect on greenhouse gases by blocking radiation
Hydrocarbons and volatile organic compounds (HC and VOC)[2]	HC are a group of chemical compounds made of hydrogen and carbon. Called VOCs when in a gaseous form. Typically the result of incomplete gasoline combustion or petrochemical industry by-products. Transportation accounts for 40-50%.	All are somewhat carcinogenic, but heavy HCs are worse than light HCs Fatal at high concentrations	Harmful to crops and accumulates in food chain Catalysts for ozone, and components of smog and acid rain

Carbon Dioxide (CO_2) A colorless, odorless gas composing 0.04% of atmosphere[2]	It is an important temperature regulator of the atmosphere It is emitted with burning of fossil fuels. Transportation accounts for about 30% of emissions in developed countries, and 15% worldwide. Within transportation, about 66% is from gasoline combustion, 16% from diesel, and about 15% from jet fuel.	High concentrations (5000 ppm) may cause breathing disorders	Essential element of photosynthesis Large quantities in the atmosphere are assumed to be linked to the greenhouse effect
Mobile Source Air Toxics (MSATs) Various compounds,	Some are present in gasoline, and are emitted when gas evaporates or are emitted with unburned fuel Many have cancerous and other health effects on humans and animals The EPA has a list of 93, with 8 key MSATs: diesel exhaust, benzene, 1,3-butadiene, acrolein, formaldehyde, acetaldehyde, naphthalene, and polycyclic organic compounds	Exposure has been linked to adverse health effects such as respiratory problems, birth defects, cardiovascular problems, and childhood cancer Many are known or suspected carcinogens, and could cause premature death Risk increases with exposure—living near sources of MSATs can significantly increase risk	MSATs are also linked to health problems in animals

Effects of Air Pollution Outcomes

Pollution Outcome	General Information	Health Effects	Environmental Effects
Smog[2]	A mix of solid and liquid fog and smoke particles formed through the accumulation of CO, ozone, HC/VOC, NOx, SOx, water, PM, and other chemical pollutants. Called 'photochemical smog' with higher HC/VOC concentration. Strongly linked to transportation and industrial activities, especially in urban areas. Particularly dense during thermal inversion.	Effects are a conjunction of its major components—especially visibility impairment	Effects are a conjunction of its major components—especially visibility impairment

Acid rain/acid decompositions (dry form)[2]	When dissolved in water, sulfuric and nitric acids (H_2SO_4 and HNO_3) lower the pH. Can be carried long distances in weather systems, and then falls as either acid rain or fog. Based on the contribution of transportation on concentrations of SO_2, NOx, and HC/VOC, it may account for 10-30% of acid rain depending on region.	May cause respiratory irritation when inhaled as a mist	Sufficient amounts of acid can damage historical structures Changes chemical composition of soil—on a large scale can reduce the available biomass (beneficial on a small scale) Can gradually destroy life in lakes and rivers by changing the pH Known to alter the ecological balance of continental ecosystems, especially in industrialized areas.
Odors Subjective perception of the sense of smell[2]	Major sources within transportation are diesel and gasoline engines, especially prevalent in smog conditions. Mostly an annoyance.		

APPENDIX C: STATE DOT DOCUMENTS REVIEWED

State	Performance Measurement
Alabama (ALDOT)	• ALDOT publishes a quarterly performance report every fiscal year which includes performance measures (PM) • None of the PM even addresses the environment, AQ, or emissions in a roundabout way • http://www.smart.alabama.gov/ReportsApp/FormSelect.aspx

Alaska (DOT&PF)	• AK has performance measures under the following categories:
	  o Maintenance and operations of state transportation systems
	  o Measurement standards/commercial vehicle enforcement
	  o Transportation and facilities construction program
	• They also have a list of measures specifically related to five end results:
	• None of these relate to the environment, AQ, or emissions
	• http://www.gov.state.ak.us/omb/results/view_programs.php?p=157
	• http://www.gov.state.ak.us/omb/results/view_details.php?p=157

Arizona (ADOT)	• ADOT has goals and strategies in their strategic plan for 2011-2015, but none for environment, AQ, or emissions.
	  o http://www.azdot.gov/Inside_ADOT/PDF/StrategicPlan.pdf
	• List of ADOT control measures and TCM
	  o http://www.azdot.gov/mpd/air_quality/pdf/Guide.pdf
	• Congestion Mitigation Air Quality (CMAQ) yearly project summaries gives the emissions savings from projects that address air quality in some way
	  o http://www.azdot.gov/mpd/air_quality/CMAQ.asp

Arkansas (AHTD)	• Their strategic plan has a section that discusses the environment and air quality, but it does not have PM. o http://www.arkansashighways.com/stip/Final_2007_Statewide_LongRange_Plan.pdf

California (Caltrans)	• Caltrans has a guidebook for PM for rural transportation systems (2006) which includes PM for safety, system preservation, mobility, accessibility, reliability, productivity, and return on investment.
	  o None of these addresses emissions or environment
	  o http://www.dot.ca.gov/hq/tsip/tspm/results/2006/ExecutiveSummaryFlier.pdf
	• Caltrans is involved in a Climate Action Team along with CalEPA and others
	• See CA Air Resources Board, http://www.arb.ca.gov/homepage.htm
	• The Caltrans Headquarters Air Quality Coordination Branch page
	  o Includes project-level air quality analysis tools, info on Clean Air Act conformity, climate change, and other links
	  o http://www.dot.ca.gov/hq/env/air/
	• Air quality and transportation planning page
	  o Includes links to important pages and documents, such as all state implementation plans and a page detailing emission reduction plans for ports and goods movement
	  o http://www.arb.ca.gov/planning/planning.htm
	• Transportation strategies and air quality page
	  o Includes links to different aspects of transportation and air quality, such as ‘bicycles and air quality’ and ‘land use and air quality’
	  o http://www.arb.ca.gov/planning/tsaq/tsaq.htm

Colorado (CDOT)	• The CDOT Annual Report has a small paragraph on their Environmental Programs Branch, but nothing besides that. It also doesn't really include PM o http://www.coloradodot.info/library/AnnualReports/2009AnnualReport.pdf/view • Their yearly Fact Book contains many statistics, but none environmentally related. o http://www.coloradodot.info/library/FactBook/FactBook10-2.pdf/view • A Neighborhood Scale Air Toxics Assessment in North Denver o http://www.coloradodot.info/programs/research/pdfs/2007/goodneighbor.pdf/view • Area-wide Coordinated Cumulative Effects Analysis o http://www.coloradodot.info/programs/research/pdfs/2008/accea.pdf/view
Connecticut (CTDOT)	• CTDOT is just starting to create a quarterly PM report (beginning Jan. 1, 2009) with the multiple performance metrics addressing the goals of safety and security, preservation, efficiency and effectiveness, quality of life, and accountability and transparency. • While some of these would vaguely relate to emissions (like reducing congestion or incident duration, and increasing biking access), none directly address emissions or environmental concerns except for using recycled materials. • http://www.ct.gov/dot/lib/dot/documents/dperformancemeasures/pmetrics.pdf • http://www.ct.gov/dot/lib/dot/documents/dperformancemeasures/pmeasures2009q4.pdf
Delaware (DelDOT)	• The 2008 DelDOT Fact Book contains some information on air quality, but no PM, or even values of emissions. It doesn't really have any PM, but most sections at least have data. o http://www.deldot.gov/information/pubs_forms/fact_book/pdf/2008/2008_fact_book.pdf (pg. 10)
Florida (FDOT)	• The website 'Florida Performs' includes PM on a variety of topics related to living in Florida, including transportation and environment/conservation. The transportation section only has measures of safety, mobility, and service. However, the environment section looks at air quality overall, as well as water quality, energy, etc. o http://www.floridaperforms.com/Area_Transportation.aspx • A long list of PM is at http://www.dot.state.fl.us/planning/policy/lrpp/exhibit2.pdf. However, none really address air quality, environment, or emissions. • http://www.floridatransportationindicators.org/index.php?chart=1a has several transportation indicators, but none related to air quality, environment, or emissions.
Georgia (GDOT)	• GDOT has statistics available, but only related to traffic, crash, and road data. o http://www.dot.state.ga.us/statistics/Pages/default.aspx • The Governor's Office of Planning and Budget publishes PM for different agencies for each fiscal year. The report for GDOT contains several PM, but none related to the environment, AQ, or emissions. o http://www.opb.state.ga.us/media/10879/department%20of%20transportation.pdf • The yearly Fact Book discusses environment some, but without PM o http://www.dot.state.ga.us/informationcenter/pressroom/Documents/publications/Fact%20Book%202008-2009.pdf
Hawaii (HDOT)	• No applicable sources found.
Idaho (ITD)	• ITD's Annual Report for FY 2009 contains some PM • While none of those relate to environmental PM, the report states that ITD will continue to develop PM during 2010. • http://itd.idaho.gov/accountability/FY09_Annual_Report.pdf

Illinois (IDOT)	• The most recent annual report online (FY2007) included a goal of "integrate concern for the environment and quality of life of Illinois citizens in the transportation planning process" and another goal of "implementation of effective objectives and measures in all areas to drive continual improvement of core processes." • However, no further reports are available online, so the progress of such goals cannot be determined. • There is also a section on policy improvement of "environmental policies to reduce the air pollution effects of highway construction" including: o AQ monitoring and reporting of AQ in the construction area o Contract provisions for dust control measures o Tougher requirements for contractors to use ultra low-sulfur fuel o Stricter rules against equipment idling o Timely and accurate reporting to communities • http://dot.state.il.us/annualreport/2007/Introduction.pdf • http://dot.state.il.us/annualreport/2007/insideoutside.pdf • http://www.dot.il.gov/pdf/RyanFactSheetEnvironmental.pdf
Indiana (INDOT)	• Their long range plan has a whole chapter on air quality. It primarily discusses ozone, particulate matter, and the Clean Air Act. But it also talks about INDOT's Congestion Mitigation and Air Quality Program. • http://www.in.gov/indot/files/05_air_quality.pdf
Iowa (Iowa DOT)	• Yearly reports from the Iowa Dept. of Management for various sectors include ones for transportation with a lot of PM for several categories. • PM related to the environment, air quality, and/or emissions include: o Number of commercial vehicles inspected transporting hazardous materials o VMT (but not as a reduction) o Number of tons of freight on different modes originating terminating in Iowa • http://www.dom.state.ia.us/planning_performance/files/reports/FY08/DOTPerformanceReportFY2008FINAL.pdf (2009) • Nothing really directly in the 2010 plan either, http://www.dom.state.ia.us/planning_performance/files/plans/performance/2010/FY10TransportationPerformancePlan.pdf
Kansas (KSDOT)	• The 2009 annual report does not directly address environmental issues, but does include things like congestion reduction and multi-modal solutions. • http://www.ksdot.org/PDF_Files/KDOTReport-09FINAL.pdf
Kentucky (KYTC)	• Their Long-Range Statewide Transportation Plan includes the goals of safety and security, system preservation, and economic opportunity and mobility. • There is one section on air quality (page 23), mainly listing their nonattainment counties. • http://www.planning.kytc.ky.gov/stp/2006/Statewide%20Plan.pdf
Louisiana (LA DOTD)	• LA has a dashboard figure at http://www8.dotd.la.gov/administration/metrics/dashboard.aspx but it only relates to construction cost and time.
Maine (MaineDOT)	• No applicable sources found.

Maryland (MDOT)	• Has a list of PM in the 2010 Annual Attainment Report on Transportation System Performance, http://www.mdot.maryland.gov/Planning/CTP_10-15/2010_Attainment_Report.pdf • This actually includes environmental PM under the following goals: • Environmental Stewardship o Transportation emissions reduction measures (TERMs) o Transportation-related emissions by region (VOCs and NOx per day for an average weekday) o Transportation-related greenhouse gas emissions (CO2, methane, N2O or nitrous oxide, CO, NOx, and non-methane VOCs) o Acres of wetlands or wildlife habitat created, restored, or improved since 2000 (with MPA, Maryland Port Administration) o TERMs (with MTA, Maryland Transit Administration) o Travel demand management (with MTA) o Compliance rate and number of vehicles tested for Vehicle Emissions Inspection Program (VEIP) versus customer wait time (with MVA, Motor Vehicle Association) o Acres of wetlands restored and miles of streams restored (with SHA, State Highway Administration) o Total fuel usage of the light fleet (with SHA) o Travel demand management (with SHA) • Other goals include: o Quality of Service, Safety & Security, System Preservation & Performance, Connectivity for Daily Life,
Massachusetts (MassDOT)	• Has a performance report, the Highway Division Scorecard at http://www.eot.state.ma.us/scorecard/downloads/ScoreCard/ScoreCardDec09.pdf, but with no environmental, air quality, or emissions performance information
Michigan (MDOT)	• Has a PM report on the transportation system condition at http://www.michigan.gov/documents/mdot/MDOT-Performance_Measures_Report_289930_7.pdf but no environmental section
Minnesota (Mn/DOT)	• Mn/DOT has an annual scorecard at http://www.dot.state.mn.us/measures/pdf/Scorecard%2011X17%205-18%20Final.pdf, but no environmental, AQ, or emissions measures • In their statewide plan, they have the goals of environmental stewardship in project development and emissions and energy consumption, with the following performance measures and targets for the second one: o Compliance with criteria air pollutant standards o Mn/DOT use of cleaner fuels ▪ Reduce the use of gasoline by on-road vehicles owned by state departments by 25 percent by 2010 and by 50 percent by 2015 ▪ Reduce the use of petroleum-based diesel fuel used by state departments by 10 percent by 2010 and by 25 percent by 2015 o National pollution discharge elimination system compliance—erosion control o Wetlands affected and replaced o Carbon dioxide emissions from the transportation sector o http://www.dot.state.mn.us/planning/stateplan/Final%20Plan%20Documents/Policy%20Plan/PDF/7P9EnergyandEnv.pdf o http://www.dot.state.mn.us/planning/stateplan/Final%20Plan%20Documents/Policy%20Plan/PDF/AppendixD.pdf
Mississippi (MDOT)	• No applicable sources found.

Missouri (MoDOT)	• MoDOT *Tracker* has performance measures, with the subsections of the 2010 report at http://www.modot.org/about/general_info/Tracker.htm • The section for environmental responsibility includes the following PM • Each PM includes a stated purpose, guidance on measurement and data collection, and its resulting improvement status • http://www.modot.org/about/general_info/documents/Tracker_Jan2010/Chapter%2010.pdf
Montana (MDT)	• No applicable sources found.
Nebraska (NDOR)	• The NDOR performance measurement report for 2009, at http://www.nebraskatransportation.org/performance/docs/dec-2009.pdf, has many performance measures including: o No loss of wetland acres o Wetland mitigation bank acres for future needs o Environmental impact statement completed o Environmental assessment completed
Nevada (NDOT)	• The NDOT Statewide Transportation Plan at http://www.nevadadot.com/planning/pdfs/NevPlan_StatewideTransPlan.pdf, has multiple strategies and objectives, including: • Strategies: o Preserve and enhance Nevada's transportation system while fostering relationships with the public and regulatory agencies o Water quality and erosion and sediment control program—prevent pollution resulting from storm water runoff and wind erosion from NDOT facilities o Ensure that Nevada's resident and affiliated Native American tribes are informed and consulted for concerns when either their current land holdings or places/resources significant to them may be affected by NDOT's projects o Work to reduce the amount of annual energy we consume at our facilities and with our vehicles and equipment • Objectives: o Ensure that all Federally funded projects meet requirements of the law under 23 CFR 771 & 772 o Reduce annual energy consumption at facilities and with our vehicles and equipment from previous year
New Hampshire (NHDOT)	• Their annual report for 2009 includes a small section on environmental issues (page 11), but not much. • http://www.nh.gov/dot/media/documents/2009AnnualReport.pdf
New Jersey (NJDOT)	• No applicable sources found.
New Mexico (NMDOT)	• NMDOT publishes a quarterly performance report, which includes PM that address programs and infrastructure, operations, program support, and the governor investment partnership • None address environment, AQ, or emissions. • http://www.nmshtd.state.nm.us/upload/images/Quality_Bureau/Q3fy10.pdf

New York (NYSDOT)	• Chapter 1.1 of their Environmental Procedures Manual is all about Air Quality (giving guidelines for projects)
	  o https://www.nysdot.gov/divisions/engineering/environmental-analysis/manuals-and-guidance/epm/repository/epmair01.pdf
	  o Chapter 1.2 is about particulate matter
	• NYSDOT sponsors Clear Air NY, with the objective of improving AQ in the NY metro area by educating the public and organizations about ways they can change their travel behavior.
	  o http://www.cleanairny.org/cleanairny/Home/Default.aspx\
	• Their 2005-2030 Transportation Plan has an environmental sustainability section (page 67), which includes a list of ongoing and future initiatives.
	  o https://www.nysdot.gov/portal/page/portal/main/transportation-plan/repository/masterplan-111406.pdf

North Carolina (NCDOT)	• Has a nice dashboard performance graphic, but it only displays fatality rate, incident duration, infrastructure health, delivery rate, and employee engagement. o http://www.ncdot.org/programs/dashboard/

North Dakota (NDDOT)	• A performance measures report card brochure reports on customer satisfaction, employee satisfaction, worker safety, highway safety, highway system condition, and project development and delivery.
	  o http://www.dot.nd.gov/divisions/exec/docs/pm-rpt-cd.pdf
	• None of their transportation goals relate to the environment
	  o http://www.dot.nd.gov/manuals/planning/TrActII-07.pdf

Ohio (ODOT)	• Ohio government site has a page with a performance graph for each department, reporting on only one aspect of that department's performance—the graph for the DOT only shows crash statistics for 2007-2008. o http://results.ohio.gov/PerformanceGoalsGraphs/tabid/64/Default.aspx
Oklahoma (ODOT)	• The 2005 System Status Report briefly mentions operations, capital outlay, engineering, administration, capital improvement program, railroads, transit, waterways, county roads, and highway construction and materials tech. Then about 50 pages are devoted to bridge problems, including many pictures of structural deficiencies. o http://www.okladot.state.ok.us/newsmedia/pdfs/systemstatus.pdf

Oregon (ODOT)	• In their 2008 State of the System Report, one goals is 'sustainability', or "creating a balance between environmental, economic, and community objectives" o There is a chapter devoted to this goal, beginning on page 22 o This chapter has sections on climate change, creating communities, energy supply, and an environmentally responsible transportation system o "ODOT plays an important role in monitoring and mitigating air quality concerns throughout the state. DMV assists the Oregon Department of Environmental Quality in enforcing vehicle emissions standards in the Portland and Medford areas. ODOT also evaluates and works to reduce the effects of proposed transportation solutions on air quality as part of the planning and project development processes." o http://www.oregon.gov/ODOT/TD/docs/StateOfTheSystem/ODOT_State_of_the_System_Report_Nov14_08.pdf o The state transportation plan gives strategies for addressing the above mentioned policies (environmentally responsible transportation system, energy supply, and creating communities) starting on pg. 58 o http://www.oregon.gov/ODOT/TD/TP/docs/ortransplanupdate/2007/OTPvol1.pdf • The FY 2008-2009 Annual Performance Progress Report presents 27 'key performance measures' and the yearly progress towards them. o Only one PM directly addresses the environment: fish passage at state culverts o Some indirectly address the environment/air quality, such as alternatives to one-person commuting and passenger rail ridership o http://www.oregon.gov/DAS/BAM/docs/KPM/2009/FY09_APPRFinalODOT.pdf • The website for House Bill 2186: MPO Greenhouse Gas Emissions Task Force is at http://www.oregon.gov/ODOT/TD/TP/HB2186.shtml
Pennsylvania (PennDOT)	• The 2008-2009 Governor's Report on State Performance (environmental section) has a goal of 'clean the air by limiting exposure to unsafe levels of air pollutants', but this is not a DOT document. o http://www.portal.state.pa.us/portal/server.pt/community/performance_reports/4677/2008-09_governor's_report_on_state_performance_(released_april_2010)/698405 • Environmental Impacts Statement Handbook at ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%20278.pdf • Project Level Air Quality Handbook at ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%20321.pdf • Environmental Assessment Handbook at ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/PUB%20362.pdf
Rhode Island (RIDOT)	• The Budget Office lists performance indicators by different departments; but none relate to the environment o http://www.budget.ri.gov/PerformanceIndicators.php
South Carolina (SCDOT)	• The Annual Accountability Report for 2008-2009 does not really address any aspects of environmental performance, except some on energy conservation o http://www.scdot.org/inside/pdfs/accountabilityreport.pdf • SCDOT has dashboards for planning and operations, but none relate to the environment, AQ, or emissions o http://www.scdot.org/inside/dashboard.shtml • The 2010 State of SCDOT report has information and statistics related to vehicle travel, road use, budgeting, use of fuel tax, transit, and accountability—but nothing on the environment. o http://www.scdot.org/inside/pdfs/state_of_scdot.pdf

South Dakota (SDDOT)	• No applicable sources found.
Tennessee (TDOT)	• The 2005 Goals, Objectives, and Policies Report has the goal of promoting stewardship of the environment, or 'protecting, preserving, and enhancing the social, historic, and natural environments of the state' and lists several objectives and policies o Later in the report, 25-year trends and transportation challenges/opportunities are presented, including land-use trends, energy trends, and air quality trends. The challenges associated with air quality are given as: ▪ Reducing transportation's total share of total emissions due to traffic and congestion ▪ Improving construction zones that create waste and pollution ▪ Convincing the public to embrace more environmentally friendly habits ▪ Understanding natural constraints, such as topography, that influence air pollution o It has a chapter on TDOT's goal to develop a performance management system o The appendices compares how different MPOs address the state's goals and plans o http://www.tdot.state.tn.us/plango/pdfs/plan/GoalsOb.pdf • The 2005 report on transportation system PM includes sample PM for each guiding principle; the sample PM for 'promoting stewardship of the environment' include: o Aviation: total population within DNL65 noise contour o Bicycles/Pedestrians: number of shared use trails along major state natural and manmade corridors o Highways: transportation-related emissions by region o Ports/Waterways: 5-year average of chemical spills o Rail: amount of funding for environmental or community restoration from rail impacts o Transit: increase/decrease in air quality pollutants in major transit corridors o However, in this report the final recommended PMs do not include any directly environmentally-related measures o The report states that for future proposed measures, the Tennessee Dept. of Environment and Conservation and MPOs would be in charge of data collection for any related to Clean Air requirements o In Appendix A, the report lists environmental PM used included in several modal plans o None of the peer states reviews (Florida, Maryland, North Carolina, Washington, Wisconsin) had environmentally-related PM listed in Appendix B o http://www.tdot.state.tn.us/plango/pdfs/plan/PerfMeasures.pdf • Clear the Air site, organized by TDOT, is a statewide program to encourage better driving habits o http://www.cleartheairtn.org/

Texas (TxDOT)	• The TxDOT 2009-2013 Strategic Plan has a section that addresses TxDOT's Goal #4: Improving Air Quality (pg. 27) o 34 counties are classified as either 'Early Action Compact' or 'Eight-Hour Ozone Non-Attainment' as of 2008 o TxDOT and partners like the TCEQ focus most emissions reduction programs on DFW, Houston-Galveston-Brazoria, San Antonio, Austin-San Marcos, Northeast Texas, and Beaumont-Port Arthur o TxDOT focuses air quality measures on June, July, and August because the heat and sun are ideal for ozone formation o The PM used for AQ is level of ozone in the air, which is in a downward trend. It shows a TCEQ graph that illustrates the tons of NOx and VOCs emitted during ozone season for the six locations in 2000 and in 2005 o States that information on particulate matter is limited due to lack of monitoring o TxDOT supports 'Drive Clean Across Texas' along with TCEQ, EPA, FHWA, etc., as a public outreach and education program to encourage emission-reducing behaviors: vehicle maintenance, less driving, purchase of 'cleaner' vehicles, driving the speed limit, and reduction in idling time. o TxDOT partners with MPOs to seek multimodal solutions to improve mobility o ftp://ftp.dot.state.tx.us/pub/txdot-info/lao/public_strategic_plan2009.pdf • TxDOT Tracker has all the goals and PMs in a table form, but the only air quality PM is GHG emissions. o http://apps.dot.state.tx.us/txdot_tracker/ • Drive Clean Across Texas at http://www.drivecleanacrosstexas.org/ • The Clean Air Plan is TxDOT's internal effort to reduce emissions by: o Using low-emission diesel fuel o Avoid refueling between 6-10am o Limit vehicle idling o Avoid mowing TxDOT property on Ozone Action Days o Encourage contractors to use new equipment to mow the ROW o Encourage contractors to avoid mowing the ROW on Ozone Action Days o Purchase solar powered light and sign boards o Use only LED signal bulbs o Use only low emission/spill-proof gas cans o Encourage contractors to apply for Texas Emission Reduction Plan grants o Send Ozone Action Day notifications o Encourage car- and vanpooling o Give priority parking to car- and vanpools o Provide DCAT training for new and current employees o Hold DCAT workshops and other clean air events o Use hybrids, dual-fuel and other alternative-fueled vehicles o Allow flexible and compressed work schedules o Offer direct deposit o Encourage public transit, commuter rail, biking, walking for commuters o Limit workday outings o Encourage vehicle maintenance and clean vehicles for commuters o http://www.txdot.gov/business/contractors_consultants/environmental/clean_air.htm

Utah (UDOT)	• On the state government site, there are performance dashboard reports for UDOT that address pavement preservation, snow and ice control, incident management, fatalities, and travel time
	  o http://performance.utah.gov/agencies/udot.shtml
	• These charts are also included in the 2009 Strategic Direction and Performance Measures report, although none of their goals relate to the environment
	  o http://www.udot.utah.gov/main/uconowner.gf?n=4309713963076909
	• UDOT's Environmental Services
	  o http://www.udot.utah.gov/main/f?p=100:pg:866760701625553:::1:T,V:241

Vermont (VTrans)	• The 2007 Annual Performance Report includes a section relating to protecting and enhancing the environment. This year's report discusses culvert fish passage and reducing emissions. o http://www.aot.state.vt.us/Documents/Annual%20report%20final%206-20-07.pdf

Virginia (VDOT)	• Can view lists of state PMs and get reports online for various state departments. For the DOT, environmentally-related PMs (out of over 50 measures) include:
	  o Environmental compliance percent
	  o Percent of state environmental review projects initiated by scheduled begin date
	  o Non-renewable energy purchase dollars
	  o http://vaperforms.virginia.gov/agencylevel/src/ViewAgency.cfm?agencycode=501&mclass=other
	  o http://vaperforms.virginia.gov/agencylevel/src/report1.cfm
	• VDOT has a dashboard PM display for performance, safety, system condition, finance, management, project delivery, and citizen survey results
	  o http://dashboard.virginiadot.org/
	• The 2008-2010 Strategic Plan has a section on 'environmental monitoring and compliance for highway projects' and on 'environmental monitoring program management and direction'
	  o http://virginiadot.org/about/resources/FY2009_Final_StrategicPlan_ServiceAreaPlan_12112007.pdf

Washington (WSDOT)	• An overview of the process they went through to develop a PM system includes a list of lessons learned that could be useful at http://www.wsdot.wa.gov/NR/rdonlyres/91089378-E709-49EF-AE42-AE80BC44A91C/0/TRB_Performance_Folio.pdf • They also have a report about using indicators in performance management at http://www.wsdot.wa.gov/NR/rdonlyres/024555DA-3CAD-4793-8FD9-8BF1CF4A6D07/0/2010_WSDOT_PerformanceManagement_Folio.pdf • WSDOT air quality brochure: o http://www.wsdot.wa.gov/NR/rdonlyres/C9C98131-8F63-4F29-BB01-8DBBDB67ABB7/0/AirQuality.pdf • WSDOT publishes a quarterly performance report called The Gray Notebook, which includes extensive information on performance. It includes an environmental section. o It is less of a long-term reporting of indicators, and more of a reporting on the performance and results of recent projects and plans. o The environmental section in the most recent report (published Feb. 2010 for the quarter ending Dec. 2009) includes information on their fish passage barriers program, environmental compliance, reportable events and violations, and National Environmental Policy Act (NEPA) documentation annual report. o Archived Gray Notebook editions can be searched by published date and by topic. For example, topics related to AQ appear in Quarter 2 of 2006, Quarter 2 of 2007, Quarter 3 of 2008, and Quarters 2 and 3 of 2009. o http://www.wsdot.wa.gov/Accountability/GrayNotebook/SubjectIndex.htm#environment • Their 2009-2015 Strategic Plan includes 5 goals (safety, preservation, mobility, environment, and stewardship) with objectives, PM, and strategies for each. For the Environment goal, the objectives are: o Storm water and Puget Sound: reduce environmental impacts from storm water discharged from WSDOT facilities o Species and Habitat Protection: protect and restore fish and wildlife habitat o Climate Change: reduce transportation contributions to climate change and address impacts of climate change on transportation infrastructure and operations o Cultural Resources: improve WSDOT's cultural resources surveys o Ferries Environmental Management: improve environmental management at State Ferries o http://www.wsdot.wa.gov/NR/rdonlyres/308B6349-A012-4482-8337-274031E879F3/0/StrategicPlan0915.pdf • The WSDOT website has a whole tab devoted to the environment o http://www.wsdot.wa.gov/Environment/default.htm#air • The WSDOT climate change page o http://www.wsdot.wa.gov/environment/climatechange/ • The 2007 WSDOT Greenhouse Gas Emissions Inventory o This report only addresses emissions released by the agency, and not by the traveling public. o http://www.wsdot.wa.gov/NR/rdonlyres/A9FD1AD6-94C1-49D9-85E5-A45815D670BD/0/WSDOT_2007_GHG_Inventory.pdf • The 2009 WSDOT Guidance for Project-Level Greenhouse Gas and Climate Change Evaluations o http://www.wsdot.wa.gov/NR/rdonlyres/73ADB679-BDA6-4947-93CA-87C157862DD7/0/WSDOTprojectLevelGHG.pdf • The 2008 WSDOT Sustainability Plan and Progress Report Update o http://www.wsdot.wa.gov/NR/rdonlyres/A66BD61B-0CB7-48F3-9403-D2542CE2B7E5/0/2008SustainabilityPlanandProgressReportUpdate_091409_final.pdf • 2007 Reducing Diesel Emissions Brochures: o Understanding Diesel Emissions at http://www.wsdot.wa.gov/NR/rdonlyres/10B3E6A6-94D0-47BE-B874-B08F7DC7CB22/0/DieselFoliopart1FinalJan2007.pdf o Progress to Date, Future Needs and Efforts at http://www.wsdot.wa.gov/NR/rdonlyres/404F0BF4-5D83-44EB-B921-DBE1F99D8BE8/0/DieselFoliopart2FinalJan2007.pdf

West Virginia (WVDOT)	• No applicable sources found.

Wisconsin (WisDOT)	• The 2008-2009 strategy report does not mention environmental goals, and neither does the 2005-2007 Biennial Report.
	  o http://www.dot.wisconsin.gov/about/docs/strategicplan.pdf
	  o http://www.dot.wisconsin.gov/library/publications/format/annual/biennial05-07.pdf
	• A collection of WisDOT research projects/reports includes an environmental section, although none of the reports are about air quality
	  o http://on.dot.wi.gov/wisdotresearch/compresprojs.htm#Environment
	• A collection of transportation synthesis reports includes:
	  o Air Quality and Modern Roundabouts
	  o Transportation and Global Warming: Defining the Connection and Solution
	  o State DOT Environmental Programs: Evaluation and Performance Measures
	  o Analyzing Mobile Source Air Toxics in the NEPA Process: Emerging State Practices and Research
	  o Restricting Diesel Idling at Construction and Distribution Sites
	  o Performance Measures for DOT Business Functions
	  o Transportation, Air Quality, and Health
	  o http://on.dot.wi.gov/wisdotresearch/comptsrs.htm#Environment
	•

Wyoming (WYDOT)	• The 2005 Long Range Transportation Plan has different goals related to different aspects of WYDOT's work.
	  o The only directly environmental-related goal (rather than mode share, etc.) was under the Public Involvement Goal area—to continue to improve compliance with NEPA through appropriate public involvement activities
	  o The only thing the report really says about NEPA is that the WYDOT Environmental Services Program is in charge of undertaking and documenting NEPA-related activities
	  o It mentions reduced fuel consumption as a result of well-executed access control (pg. 37)
	  o Has a short section on the environment, where it states that although Sheridan was non-attainment in the 80s for particulate matter, it has been in compliance since the 90s so they are trying to get that designation changed. It is the only AQ problem area.
	  o Chapter 13 is directly about environmental compliance, which discusses compliance with NEPA, cultural resource protection, wetlands and water quality protection, endangered species and biological resources protection, reclamation, and air quality.
	  o It states that they have plans to "initiate long-term studies and monitoring standards statewide to control the impact of WYDOT activities to Wyoming's air quality."
	  o http://www.dot.state.wy.us/webdav/site/wydot/shared/Planning/Long%20Range%20Report.pdf
	• They have an interactive dashboard, but it only shows customer satisfaction, fatalities, seatbelt usage, and pavement conditions.
	  o http://www.dot.state.wy.us/wydot/administration/strategic_performance/strategic_plans/dashboard
	• The website states that "WYDOT is currently in the process of developing balanced scorecards (BSCs) for all of the organizational units within the department." It has files for different areas, which give a matrix of goals, measures, strategies, targets, actual values, comments, and last years.
	  o The Planning Program's BSC has a few strategies that address the environment, such as "provide leadership for environmental stewardship", but no goals. The only measure and target is 100% approval of NEPA documents by the FHWA. This was the only document that seemed to have anything, and there was no specific environmental document.
	  o http://www.dot.state.wy.us/wydot/administration/strategic_performance/program_performance_measures
	• The 2008-2009 Fact Book does not have any environmental/emissions data
	  o http://www.dot.state.wy.us/webdav/site/wydot/shared/Strategic_Performance_Improvement/2008%20Fact%20Book.pdf
	• They have 23 Performance Indicators, but none environmentally related
	  o http://www.dot.state.wy.us/wydot/administration/strategic_performance/pid/787
	• Brief info on Environmental Services at http://www.dot.state.wy.us/wydot/engineering_technical_programs/environmental_services

APPENDIX D: PERFORMANCE MEASURE LIST CATEGORIZED BY SOURCE AND TYPE

Emissions

Transport emissions—CO_2, N_2O, NOx, SOx, PM, VOCs, ozone, CO, lead, benzene, etc. (some form of this PM is included in most of the sources)

Transportation-related emissions by region (VOCs and NOx per day for an average weekday) (MDOT)[1]

Transportation-related greenhouse gas emissions (CO2, methane, N2O or nitrous oxide, CO, NOx, and non-methane VOCs) (MDOT)[1]

Emissions versus vehicular travel (USEPA 1999, Gudmundsson)[2, 3]

VOC emissions from solvent utilization in surface coating for autos and light trucks (USEPA 1999, Gudmundsson)[2, 3]

Other pollutants from vehicle and equipment manufacturing (USEPA 1999, Gudmundsson)[2, 3]

Emissions from airport service vehicles (USEPA 1999)[2]

VOC emissions from solvent utilization in surface coating for autos and light trucks (USEPA 1999)[2]

VOC emissions from service stations (USEPA 1999)[2]

Mobile source contribution to hazardous air pollution inventories (USEPA 1999, Gudmundsson)[2, 3]

Toxic chemicals released from ship and boat building and repairing facilities (USEPA 1999)[2]

Waste from road vehicles, including tires and oil (TERM, STPI)[4, 5]

Emissions impacting water quality? Like sediment loads in streams? (STPI)[6]

Emissions of ozone-depleting substances (STPI)[6]

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[1] Maryland Department of Transportation. 2010 Annual Attainment Report on Transportation System Performance. MDOT, Hanover, Maryland, 2010.

[2] Environmental Protection Agency. *Indicators of the Environmental Impacts of Transportation, Second Edition.* U.S. EPA, Washington, D.C., 1999.

[3] Gudmundsson, H. *Indicators and Performance Measures For Transportation, Environment, and Sustainability in North America*. Report from a German Marshall Fund Fellowship 2000 individual study tour, National Environmental Research Institute, Denmark, October 2000.

[4] European Environment Agency. Towards a Resource-Efficient Transportation System: Indicators Tracking Transport and Environment Integration in the European Union. *Term 2009.* EEA, Copenhagen, 2010.

[5] Gilbert, R., N. Irwin, B. Hollingworth, P. Blais, H. Lu, and N Brescacin. *Sustainable Transportation Performance Indicators (STPI) Project, Phase 3*, Centre for Sustainable Transport, with IBI Group and Metropole Consultants, Canada, December 31, 2002.

[6] Gilbert, R., and H. Tanguay. Brief Review of Some Relevant Worldwide Activity and Development of an Initial Long List of Indicators. *Sustainable Transportation Performance Indicators (STPI) Project, Phase 1*, Centre for Sustainable Transport, University of Winnipeg, Canada, June 2000.

Index of specified transport emissions in relation to defined absorption capacity (STPI) [6]

Index of specified transport wastes in relation to defined absorption capacity (STPI) [6]

Index of fleet emissions intensity (STPI) [5]

Marine oil discharges (STPI) [5]

Global atmospheric concentration of GHGs (STPI) [6]

GHG emissions from transportation (STPI, WSDOT) [5, 7]

Removal of GHGs (New Zealand Ministry of Environment) [8]

Tons of pollutants generated (NCHRP 446) [9]

Air quality rating (NCHRP 446) [9]

Compliance

Number of new non-attainment areas (NCHRP 446, WSDOT) [9, 10]

Frequency of air pollution standard violations (Litman 2009) [11]

Air quality index ratings (Litman 2009) [11]

Average monthly ambient air concentrations in a particular location (STPI) [6]

Air quality levels or exceedances (STPI) [5]

Number of occasions that ambient concentrations are in excess of relevant standards, in areas where the impact of transport emissions is significant (New Zealand Ministry of Transport) [12]

Highway emissions levels within non-attainment areas (NCHRP 446) [9]

VMT/Mode Share/Vehicles/etc.

VMT per capita, by corridor, by mode, statewide (WSDOT, Litman 1999) [13, 14]

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[7] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 34th Edition, Quarter 2, ending June 30, 2009, published August 20, 2009.

[8] Ministry for the Environment. *Environment New Zealand 2007*. Ministry for the Environment, Wellington, New Zealand, 2007.

[9] Cambridge Systematics, Inc. *NCHRP Report 446: A Guidebook for Performance-Based Transportation Planning.* National Cooperative Highway Research Program, Transportation Research Board, National Research Council, Washington, D.C., 2000.

[10] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 31st Edition, Quarter 3, ending September 30, 2008, published November 25, 2008.

[11] Litman, T. *Well Measured: Developing Indicators for Comprehensive and Sustainable Transport Planning*. Victoria Transport Policy Institute, BC, Canada, December 9, 2009.

[12] Ministry of Transport. *Transport Monitoring Indicator Framework, Version 2.* Ministry of Transport, Wellington, New Zealand, 2009.

Commute mode share trends (WSDOT, STPI) [15, 5]

Drive alone rate (WSDOT) [13]

Occupancy rates of park-and-ride lots (WSDOT) [16]

Vanpools share of area VMT (WSDOT) [17]

Rail ridership by month, year, or segment (WSDOT) [18, 19]

Truck counts/share of total daily vehicle volume (WSDOT) [18]

Number of public transit users (MoDOT, Litman 2009) [20, 11]

Number of intercity bus stops (MoDOT) [20]

Number of rail passengers (MoDOT) [20]

State funding for multimodal programs (MoDOT) [20]

Trips by foot or bicycle per capita (Litman 2009) [11]

Passenger transport volume and modal split (TERM) [4]

Freight transport volume and modal split (TERM) [4]

Size of the vehicle fleet (TERM) [4]

Average age of the vehicle fleet (TERM) [4]

Proportion of vehicle fleet meeting certain emission standards (TERM) [4]

Passenger and freight demand projections (TERM) [4]

Change in level of road congestion over time (STPI) [6]

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[13] Washington State Department of Transportation. *The 2009 Congestion Report: Gray Notebook Special Edition*. 35th Edition, Quarter 3, ending September 30, 2009, published November, 2009.

[14] Litman, T. *Sustainable Transportation Indicators*. Victoria Transport Policy Institute, BC, Canada, November 29, 1999.

[15] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 13th Edition, Quarter 1, ending March 31, 2004, published May 20, 2004.

[16] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 23rd Edition, Quarter 3, ending September 30, 2006, published November 22, 2006.

[17] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 15th Edition, Quarter 3, ending September 30, 2004, published November 15, 2004.

[18] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 37th Edition, Quarter 1, ending March 31, 2010, published May 21, 2010.

[19] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 3rd Edition, Quarter 3, ending September 30, 2001.

[20] Missouri Department of Transportation. *Tracker: Measures of Departmental Performance*. MoDOT, Jefferson City, Missouri, April 2010.

Non-auto trips (percent of urban trips not by auto) (STPI) [6]

Traffic volumes of road, rail, air, sea (in VMT) (STPI) [6]

Passenger-miles (STPI) [6]

Freight ton-miles (STPI) [6]

Percent of inter-urban passenger trips by mode of transport (STPI) [6]

Transit ridership (STPI) [6]

Total motorized movement of people (STPI) [5]

Total motorized movement of freight (STPI) [5]

Share of motorized movement of people not by land-based public transportation (STPI) [5]

Percentage of labor force regularly telecommuting (STPI) [5]

Construction

Use of recycled materials (CTDOT) [21]

AQ monitoring and reporting in the construction area (IDOT) [22]

Contract provisions for dust control measures (IDOT) [22]

Tougher requirements for contractors to use ultra low-sulfur fuel (IDOT) [22]

Stricter rules against equipment idling (IDOT) [22]

Percent of projects completed without environmental violation (which includes a Letter of Warning (LOW) or a Notice of Violation (NOV)) (MoDOT) [20]

Number of tons of recycled/waste materials used in construction projects (MoDOT) [20]

Environmental compliance percent (VDOT) [23]

Control of fugitive dust during construction (WSDOT) [24]

Project-level

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[21] Connecticut Department of Transportation. *Summary of CTDOT Performance Measures, Quarter 4, 2009*. Transportation Infrastructure Performance Management, CTDOT, Newington, Connecticut, revised March 25, 2010.

[22] Illinois Department of Transportation. *2007 Annual Report*. IDOT, Springfield, Illinois, 2008, pp. 51.

[23] Council on Virginia's Future. *Virginia Performs: Department of Transportation*, 2010. <http://vaperforms.virginia.gov/agencylevel/src/ViewAgency.cfm?agencycode=501&mclass=other>. Accessed March 2010.

[24] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 26th Edition, Quarter 2, ending June 30, 2007, published August 31, 2007.

Transportation emissions reduction measures (or ‘TERMs’) (MDOT) [1]

Travel demand management (MDOT) [1]

Environmental impact statement completed (NDOR) [25]

Environmental assessment completed (NDOR) [25]

Percent of projects covered by FHWA’s list of categorical exclusions under NEPA (WSDOT) [26]

Completion time in months of environmental assessment and environmental impact statements by year (WSDOT) [26]

100% approval of NEPA documents by FHWA (WYDOT) [27]

Percent of state environmental review projects initiated by scheduled begin date (VDOT)[23]

Number of environmental problems to be taken care of with existing commitments (NCHRP 446) [9]

Number of TCMs accomplished vs. planned (NCHRP 446) [9]

Environmentally friendly partnership projects per year (NCHRP 446) [9]

Ecosystem

Number of projects MoDOT protects sensitive species or restores habitat (MoDOT) [20]

Ratio of acres of wetlands created compared to the number of acres of wetlands impacted (MoDOT) [20]

Number of historic resources avoided or protected as compared to those mitigated (MoDOT) [20]

Sediment level in streams, heavy metals, etc. (STPI) [6]

Non-renewable resource consumption in the production and use of vehicles and transport facilities (Litman 2009) [11]

Smoke emission/smog

Public Health

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[25] Nebraska Department of Roads. *Performance Measures: A Performance Based Transportation Agency*. NDOR, Lincoln, Nebraska, December 2009.

[26] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 36th Edition, Quarter 4, ending December 31, 2009, published February 19, 2010.

[27] Wyoming Department of Transportation. *Balanced Scorecards: Planning Program’s BSC*. Planning Program, WYDOT, Cheyenne, Wyoming, October 2008, pp. 2. <http://www.dot.state.wy.us/webdav/site/wydot/shared/Strategic_Performance_Improvement/Planning%20BSC.pdf>. Accessed March 2010.

Exposure to unsafe levels of air pollutants (Pennsylvania Office of the Budget) [28]

Percent of Missouri's clean air days (MoDOT) [20]

Number of days pollution standard index is in an unhealthful range (NCHRP 446, Gudmundsson) [9, 3]

Medical costs attributed to transportation pollution-related diseases (Litman 1999) [14]

Number of asthma cases (Litman 2009) [11]

Population exposed to exceedances of urban air quality standards (TERM) [4]

Number of cases of serious pollution or health effects (STPI) [6]

Index of the prevalence of transport-related diseases in humans (STPI) [6]

Proximity of infrastructure to sensitive areas (STPI) [5]

Health effects (STPI) [5]

Social cost of transport-related air pollution to human health (New Zealand Ministry of Transport) [12]

Percentage of population residing in areas where the impact of transport emissions is significant (New Zealand Ministry of Transport) [12]

Population of non-attainment areas (NCHRP 446) [9]

At-risk population of non-attainment areas

Public Education/Outreach

Timely and accurate reporting to communities (IDOT) [22]

Customer perception of satisfaction with air quality (NCHRP 446) [9]

Public awareness (TERM) [4]

Extent of public support for 'green' transport (STPI) [5]

Customer perception of satisfaction with transportation decisions which impact the environment (NCHRP 446) [9]

Internal to Agency

Use of LED warning lights in maintenance fleet (WSDOT)[29]

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[28] Governor's Budget Office. *2008-09 Governor's Report on State Performance*. Pennsylvania Office of the Budget, April 2010.

[29] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 22nd Edition, Quarter 2, ending June 30, 2006, published August 22, 2006.

Filter installation in maintenance fleet (WSDOT) [29]

Emissions from state DOT vehicle fleet and equipment (NDOT, WSDOT) [30, 7]

Emissions from state traffic services (traffic signals, street lights) (WSDOT) [7]

Emissions from DOT facilities (from utilities used) (NDOT, WSDOT) [30, 7]

Emissions from shore-side operations at ports (WSDOT) [7]

Reduction in utilities at DOT facilities from updated heating and ventilation (WSDOT) [7]

Emission reductions from converting to low-sulfur diesel fuel use in state fleet (WSDOT) [31]

Energy costs of traffic signals (WSDOT) [19]

Conversion of traffic signals from incandescent to LED (WSDOT) [19]

Implementation of integrated strategies (TERM) [4]

Institutional cooperation (TERM) [4]

Monitoring systems (TERM) [4]

Implementation of SEA (TERM) [4]

Freight

Number of commercial vehicles inspected transporting hazardous materials (Iowa DOT) [32]

Tons of freight on different modes originating/terminating in the state (Iowa DOT) [32]

Freight tonnage by mode (MoDOT) [20]

Freight tonnage by year and product (WSDOT) [18]

Freight efficiency (STPI) [5]

Inspection/Maintenance

Compliance rate and number of vehicles tested for Vehicle Emissions Inspection Program (VEIP) versus customer wait time (with MVA, Motor Vehicle Association) (MDOT) [1]

Fuel/Energy Usage

Total fuel usage of the light fleet (with SHA) (MDOT) [1]

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[30] Nevada Department of Transportation. *Statewide Transportation Plan—Moving Nevada Through 2028*. Intermodal Planning Division, NDOT, Carson City, Nevada, September 2008.

[31] Washington State Department of Transportation. *Measures, Markers, and Mileposts: The Gray Notebook*. 17th Edition, Quarter 1, ending March 31, 2005, published May 17, 2005.

[32] Iowa Department of Transportation. *Performance Report, FY 2008*. IDOT, Ames, Iowa, 2009.

Number of gallons of fuel consumed (MoDOT) [20]

Non-renewable energy purchase dollars (VDOT) [23]

Gasoline consumption and prices (WSDOT) [13]

Fuel consumption per VMT (NCHRP 446) [9]

Fuel consumption per PMT (NCHRP 446) [9]

Fuel consumption per ton-mile traveled (NCHRP 446) [9]

Average fuel consumption per trip for selected trips (or shipments) (NCHRP 446) [9]

Average miles per gallon (NCHRP 446) [9]

Number of privately owned hybrid and alternative fuel vehicles (AFVs) (Litman 2009) [11]

City vehicles that are hybrid or AFV (Litman 2009) [11]

Policies to promote purchase and use of hybrids and AFVs (Litman 2009) [11]

Number of hybrid or AFV taxis (Litman 2009) [11]

Number of conventional vehicles (Litman 2009) [11]

Per capita vehicle fuel consumption (Litman 1999) [14]

Per capita fuel consumption, by fuel and mode (Litman 2009) [11]

Availability of alternative fuel (Litman 2009) [11]

Ratio of public vs. private transport energy use per passenger mile (Litman 2009) [11]

Energy consumption per freight ton-mile (Litman 2009) [11]

Use of renewable fuels (Litman 2009) [11]

Transport facility resource efficiency (i.e. use of renewable materials, energy efficient lighting, etc.) (Litman 2009) [11]

Transport final energy consumption by mode (TERM) [4]

Fuel prices and taxes (TERM) [4]

Energy efficiency (TERM, STPI) [4, 6]

Uptake of cleaner and alternative fuels (TERM) [4]

Achievement of biofuels targets (TERM) [4]

Fossil fuel consumption (STPI) [6]

Fuel efficiency of new autos (STPI) [6]

Per-capita use of transportation energy (STPI) [6]

Per-capita gasoline consumption vs. urban density (STPI) [6]

Non-fossil fuel use (STPI) [6]

Fuel use per capita (STPI) [6]

Fuel use per person-trip (STPI) [6]

Per-capita automobile use (STPI) [6]

Final energy consumption by modes and fuel type (STPI) [6]

Index describing the rates of use of non-renewable materials in relation to the rates of growth of production of renewable replacements (STPI) [6]

Index of the degree of reuse and recycling in relation to the amounts of potential waste from production and use (STPI) [6]

Index describing the rates of use of renewable resources in relation to the rates of their regeneration (STPI) [6]

Index of energy intensity of cars and trucks (STPI) [5]

Alternative fuel use (STPI) [5]

Other

Recurrent and non-recurrent congestion (WSDOT) [10]

Uptake of environmental management systems by transport companies (TERM) [4]

Percentage of reused or recycled parts of different types of end-of-life vehicles (STPI) [6]

APPENDIX E: COMPENDIUM OF PERFORMANCE MEASURES – ORGANIZED BY SCOPE AND APPLICATION

Mobile Sources Within the Scope of this Project:

Mobile Sources of Potential Concern for TxDOT			
Category	**Type**		**Description**
On-Road Vehicles	Light-duty vehicles		Passenger cars
	Light-duty trucks		Includes pickup trucks, minivans, passenger vans, and SUVs;
			Light light-duty trucks have a Gross Vehicle Weight of less than 6,000 lbs, while heavy light-duty trucks go up to 8,500 lbs
	Heavy-duty vehicles		Includes large pickups, buses, delivery trucks, RVs, and semi trucks;
			Have heavy-duty engines and a Gross Vehicle Weight over 8,500 lbs
	Medium-duty passenger vehicles		Includes large SUVs and passenger vans;
			A subset of heavy-duty vehicles, these primarily transport people and have a Gross Vehicle Weight between 8,500 and 10,000 lbs
	Motorcycles		Design for on-road use, 2 or 3 wheels
Nonroad Vehicles, Engines, and Equipment	Nonroad gasoline, diesel, and “other” equipment and vehicles	Construction equipment/vehicles owned or operated by TxDOT	Includes pavers and paving equipment (for asphalt and concrete), tampers/rammers, plate compactors, concrete pavers, rollers, scrapers, surfacing equipment, signal boards, trenchers, bore/drill rigs, excavators, concrete/industrial saw, cement and mortar mixes, cranes, graders, nonroad trucks, crushing/processing equipment, rough terrain forklifts, rubber-tire loaders and dozers, tractors/loaders/backhoes, crawler tractors, skid steer loaders, nonroad tractors, dumpers/tenders, and others.
		Lawn and garden equipment	Primarily ROW mowing
	Aircraft		Includes all type of aircraft
	Marine vessels		TxDOT ferries operating from Port Aransas and Galveston-Port Bolivar
	Locomotives		Includes diesel-powered engines only (not coal- and wood-fired) used in both freight and passenger rail, line-haul, local, and switch yard service.

Objective	Potential Measure	Potential Means of Application
Reduce the impact of mobile-sources on the quality of air	Amount of emissions per year of any of the following:□NOx□methane□N2O□CO□ozone□particulate matter□non-methane VOCs□SOx□lead□chlorofluorocarbons (CFCs)□MSATs like benzene□Total emissions□□Alternatively, some values could be grouped in an indicator like the Air Quality Index, which includes ozone, CO, and PM.□□Measures of ambient air quality levels per month could also be useful, especially with special attention to non-attainment areas. Emissions could be measured by county or TxDOT region as well as the state as a whole.	TxDOT on- and off-road transportation-related equipment (mobile)
		TxDOT construction vehicles (total or per project)
		TxDOT operations and maintenance vehicles (total or per project)
		Other vehicles in the TxDOT fleet, such as passenger cars
		State-operated ferries (Port Aransas and Galveston-Port Bolivar)
		Shore-side operations at ports involving mobile sources
		Vehicles used at airports
		Passenger cars (could be further broken down into gasoline, hybrid, AFVs, etc.)
		Light Trucks/Commercial vehicles
		Heavy Trucks/Commercial vehicles
		Bus
		Railway travel/freight transport
		Maritime travel/freight transport
		Air travel/freight transport
		Idling, especially of heavy vehicles or ships in port
	Percent change in emissions from previous year for the above possible pollutants.	Same as above
	Total transport-related emissions as a ratio to the national average.	Compilation of emissions from as many above sources as measured
	Percent of time vehicle spends idling	Construction vehicles, possibly per project
		Trucks/commercial vehicles
		Ships in port
Reduce the impact of other equipment and activities related to transportation (non-mobile)	Amount of emissions as above, or evaluated in some other way (on a case-by-case basis?) for equipment and other transportation-related activites	TxDOT on- and off-road transportation-related equipment (non-mobile)
		Any other TxDOT equipment, such as construction-related equipment
		State traffic services (traffic signals, street lights, etc.)
		Shore-side operations at ports involving non-mobile sources
		Non-mobile equipment used at airports
		TxDOT facilities (such as emissions from utility use)
		Vehicle manufacturing (all vehicle types)
		Vehicle refueling
		Evaporation of oil spills related to transportation
	Percent of TxDOT projects implementing dust control measures	For construction, or other activities, including projects carried out by a contractor
	Percent of contractors using ultra-low sulfur fuel	Contractors involved in transportation-related activities

	Percent of mowing performed on Ozone Action Days	Either in-house or contracted, could include both the ROW and TxDOT facilities
Improve the vehicle fleet in Texas to lessen emissions	Average vehicle age	All TxDOT vehicles, or different categories of TxDOT vehicles
		Passenger Cars
		Light Trucks
		Heavy Trucks
		Bus
		Rail
		Maritime
		Aviation
	Percent of vehicles older than a desired age	All TxDOT vehicles, or different categories of TxDOT vehicles
		Passenger Cars
		Light Trucks
		Heavy Trucks
		Bus
		Rail
		Maritime
		Aviation
	Percent of vehicles meeting desired emission standards	All TxDOT vehicles, or different categories of TxDOT vehicles
		Passenger Cars
		Light Trucks
		Heavy Trucks
		Bus
		Rail
		Maritime
		Aviation
	Number of vehicles tested as part of a vehicle emissions inspection program	By area or state total
	Number of vehicles reported as part of TCEQ's Smoking Vehicle Program	By area or state total
	Percentage of reused or recycled parts of different types of end-of-life vehicles	By mode
Improve the construction process to address air quality	Frequency of air quality monitoring and reporting in construction	By area
		State total
		Per project
	Percent of contractors applying for TERP Grants	By area
		State total
		Per project
Monitor actual air quality conditions in Texas	Number of non-attainment areas in Texas	Total for state
	Percent of Texas counties classified as non-attainment	Total for state or by TxDOT region
	Frequency of air pollution standard violations/exceedances per year	By TxDOT region
		By non-attainment areas
		State total
	Number of Ozone Action Days per year	By TxDOT region
		By non-attainment areas
		State total
	Average monthly ambient air concentrations of pollutants	By TxDOT region
		By non-attainment areas

		State total
Monitor and reduce the amount of greenhouse gases related to transportation	Amount of emissions of GHGs (methane and NOx in addition to CO2), potentially in some sort of index Note: TxDOT already has a measure for CO2 emitted	TxDOT on- and off-road transportation-related equipment (mobile and non-mobile)
		TxDOT construction vehicles (total or per project)
		TxDOT operations and maintenance vehicles (total or per project)
		Other vehicles in the TxDOT fleet, such as passenger cars
		State-operated ferries (Port Aransas and Galveston-Port Bolivar)
		Shore-side operations at ports
		Vehicles and equipment used at airports
		Any other TxDOT equipment, such as construction-related equipment
		State traffic services (traffic signals, street lights, etc.)
		TxDOT facilities (such as emissions from utility use)
		Passenger cars (could be further broken down into gasoline, hybrid, AFVs, etc.)
		Light Trucks/Commercial vehicles
		Heavy Trucks/Commercial vehicles
		Bus
		Railway travel/transport
		Maritime travel/transport
		Air travel/transport
		Idling, especially of heavy vehicles or ships in port
		Vehicle manufacturing (all vehicle types)
		Vehicle refueling
		Evaporation of oil spills related to transportation
	Percent change in GHG emissions from previous year for the above possible pollutants.	Same modes chosen, as above
	Total transport-related GHG emissions as a ratio to the national average.	Compilation of emissions from as many above sources as measured
	Removal of GHGs as a result of TxDOT projects	By region or state total Alternatively, the percent of projects that address GHG removal
Reduce fuel consumption to reduce CO2 emitted	Average fuel efficiency	All TxDOT vehicles, or different categories of TxDOT vehicles
		Passenger Cars
		Newly manufactured passenger cars for comparison
		Light Trucks
		Heavy Trucks
		Bus
		Rail
		Maritime
		Aviation

	Gallons of fuel consumed	Same modes chosen, as above□□Further broken down into fuel types, such as gasoline, diesel, and alternative fuels□□Could also be reported per capita
		Gasoline
	Total cost of fuel purchased per year, and average price per year	Diesel
		Alternative fuels
		Other
	Availability of alternative fuel	By region
	Percent of biofuel targets achieved	Per region or state total
		All TxDOT vehicles, or different categories of TxDOT vehicles
		Passenger Cars
		Light Trucks
	Percent of vehicles that are hybrid or alternative fuel vehicles (AFVs)	Heavy Trucks
		Bus
		Rail
		Maritime
		Aviation
	Percent of yearly vehicles purchased that are hybrids or AFVs	State vehicles
		Private vehicles
Mitigate the effect of climate change	Number of projects that involve the goal of addressing potential impacts of climate change, especially on the transportation system	Per region or state total
		From construction equipment and vehicles
	Amount and/or composition of runoff	From maintenance and operations equipment and vehicles
		From other vehicles
	Percent of rainfall that is acidic	Possibly by county or region, especially non-attainment areas
Improve water quality	Acidity of lakes and streams	Possibly by county or region, especially non-attainment areas
	Level of transportation-related pollutants found in lakes and streams, such as sediment level	Possibly by county or region, especially non-attainment areas
	Chemical composition of soil	Possibly by county or region, especially non-attainment areas
	Frequency of noted health effects in animal species	Possibly by county or region, especially non-attainment areas
Reduce other ecosystem damage, including damage to plant and animal species	Number of endangered species residing in non-attainment areas	To represent at-risk population of animal species
	Number of projects that protect sensitive species or habitats from effects of emissions	Possibly by county or region, especially non-attainment areas
	Number of commercial vehicles inspected transporting hazardous materials	Possibly by county or region, especially non-attainment areas
		By region, non-attainment area, and state total
Reduce exposure to dangerous air	Number of days the Air Quality Index (AQI) is in an unhealthful range (values above 100)	Separately indicate number of orange, red, and purple days
	Population exposed to exceedances of urban air quality standards	By region, non-attainment area, and state total

	Total population in non-attainment areas	By area and state total
	"At-risk" population in non-attainment areas	By area and state total
		*Note: the at-risk population can include children, the elderly, asthmatics, people with heart or lung disease, and the very active or those outdoors extensively
Reduce medical problems associated with transportation-related pollution	Number of medical cases attributed to transportation-related pollution	By region, non-attainment area, and state total
	Percent of the above medical cases involving children	By region, non-attainment area, and state total
	Total cost associated with medical cases attributed to transportation-related pollution	By region, non-attainment area, and state total
	Number of new asthma cases	By region, non-attainment area, and state total
Minimize 'annoyances' associated with transportation-related pollution	Frequency of transportation-related odors	By region, non-attainment area, and state total
	Percent of time noticable smog exists in urban areas	By area or state total
Reduce TxDOT energy use	Percent of lights that are LED (as opposed to incandescent)	Warning lights in maintenance fleet
		Traffic services (traffic signals, street lights, etc.)
	Frequency of conversion from incandescent to LED	Warning lights in maintenance fleet
		Traffic services (traffic signals, street lights, etc.)
	Percent reduction in utilities at DOT facilities from updated heating and ventilation, and other activities	By facility, region, state total
Better address emission problems through TxDOT projects	Number of transportation emissions reduction measures (TERMs) implemented per year	By region, non-attainment area, or state total
	Percent reduction in emissions achieved by any project aimed at reducing emissions, or any thing, such as miles traveled	By region, non-attainment area, or state total
	Number of environmentally friendly partnership projects per year	By region, non-attainment area, or state total
	Percent of TCMs accomplished versus planned	By region, non-attainment area, or state total
	Percent of funding devoted to air quality-related projects and programs	By region, non-attainment area, or state total
	Number of environmental problems to be taken care of with existing commitments	By region, non-attainment area, or state total
	Percent of projects covered by FHWA's list of categorical exclusions under NEPA	By region, non-attainment area, or state total
	Percent of approval of NEPA documents by the FHWA	By region, non-attainment area, or state total
	Percent of state environmental review projects initiated by scheduled begin date	By region, non-attainment area, or state total
	Completion time in months of environmental assessments by year	By region, non-attainment area, or state total
	Completion time in months of environmental impacts statements by year	By region, non-attainment area, or state total
	Percent of projects completed without any environmental violations	By region, non-attainment area, or state total
Better address emission problems through	Number of employee training sessions to educate on reducing air pollution through personal action	By office, region, or state total

TxDOT employee actions	Incentive programs to encourage employee reduction of emissions	By office, region, or state total
	Number (or presence) of employee requirements for operating state vehicles that pertain to emission reduction	By office, region, or state total
Increase air quality monitoring	Percent of counties equipped with air quality monitoring systems	By region and state total
Improve accountability and public outreach	Frequency of reporting performance to the public and other stakeholders	By office, region, or state total
	Customer perception of satisfaction with air quality	By office, region, or state total
	Customer perception of satisfaction with transportation decisions which impact the environment	By office, region, or state total
	Number of public outreach programs per month or year	By office, region, or state total
	Percent of citizens reached by education and outreach programs	By office, region, or state total
Monitor mileage	Yearly VMT for passenger travel by mode	Personal vehicle
		Vanpool
		Bus
		Other transit
		Ferry
		Air
	Yearly VMT or freight ton-miles by mode	Trucking
		Rail
		Maritime
		Aviation
	Yearly VMT of state vehicles	By region or state total
	Total yearly VMT	By facility, region, or state total
	Total yearly VMT per capita	By facility, region, or state total
	Percent change in VMT over time	For any above category
Monitor mode shares	Size of vehicle fleet (number of vehicles)	All TxDOT vehicles, or different categories of TxDOT vehicles
		Passenger Cars
		Light Trucks
		Heavy Trucks
		Bus
		Rail
		Maritime
		Aviation
	Freight tonnage by mode	Trucking
		Rail
		Maritime
		Aviation
	Truck percentage of VMT on roadways	By facility, region, or state total
	Commute mode share percentages for major urban areas	By facility, region, or state total
Monitor other	Drive alone rate for major urban areas	By facility, urban area, region, or state total

factors that could affect emissions	Number of carpool vehicles estimated from volumes on HOV lanes	By facility, urban area, region, or state total
	Occupancy rates of park-and-ride lots	By urban area, region, or state total
	Number of public transit users	By urban area, region, or state total
	Availability of public transit in urban areas	By urban area, region, or state total
	Trips by foot or bicycle	By urban area, region, or state total
	Percentage of labor force regularly telecommuting	By urban area, region, or state total
	Freight efficiency (amount of cargo carried versus capacity) by mode	By urban area, region, or state total in addition to mode
	Change in level of road congestion over time	By facility, urban area, region, or state total
	Average temperatures by month	By urban area, region, or state total
	Other climate factors such as wind patterns	By urban area, region, or state total

APPENDIX F: DEVELOPMENT OF AN IN-DEPTH AIR QUALITY PERFORMANCE MEASUREMENT FRAMEWORK

The following represents one incarnation of the AQ framework developed for this project, and demonstrates the process of identifying 'good' measures by explicitly considering how its selection is justified (i.e. the aspect of 'relevance'). For each potential measure, a description of how it relates to achieving the goal is included, as well as the direction (i.e. increase/decrease) that would contribute to the goal. Other aspects that could be evaluated include controllability of the measure and how significantly increased performance would contribute to the goal.

Goal: Reduce transportation-related pollutant emissions			
Objective	**Suggested Indicator**	**Justification**	
		Linkage to Goal	**Desired Direction**
Reduce pollutant emissions from on-road sources by improving operations	Percent of time vehicles spend idling by mode	Extended idling can cause more emissions than start/stop	Decrease
	Annual VMT for passenger travel by mode	VMT is needed to calculate emissions with current models; increased VMT will increase emissions	Decrease
	Annual VMT of freight or freight ton-miles by mode		Decrease
	Total annual VMT		Decrease
	Total annual VMT per capita		Decrease
	Size of vehicle fleet (number of vehicles)	More vehicles can directly contribute to more emissions, as well as contribute indirectly like causing more congestion	Decrease
	Freight tonnage on-road	Heavier freight may cause more emissions	Decrease
	Freight efficiency (amount of cargo carried versus capacity) of on-road vehicles	Inefficient freight movement may cause more trips to be necessary	Increase
	Truck percentage of VMT on roadway	Trucks emit more than passenger cars	Decrease (however, a decrease due to more passenger cars is not necessarily desirable)
	Commute mode share percentages for major urban areas	Alternate modes may emit less than passenger cars, and may decrease congestion	Increase in use of alternate modes
	Trips by foot or bicycle		Increase
	Drive alone rate for major urban areas	Carpooling decreases number of vehicles on the road, and congestion	Decrease
	Number of carpool vehicles estimated from volumes on HOV lanes		Increase

	Occupancy rates of park-and-ride lots	Increased use of alternate passenger modes could reduce congestion	Increase
	Number of on-road public transit users (i.e. bus)		Increase
	Availability of on-road public transit in urban areas		Increase
	Percentage of labor force regularly telecommuting	Eliminates vehicle trips	Increase
	Change in level of congestion over time	Increased congestion causes more emissions due to vehicle idling	Decrease
	Percent of refueling performed between 6am to 10am	More gasoline evaporation occurs between 6 and 10 am	Decrease
Reduce pollutant emissions from on-road sources by improving technology	Average vehicle age	Older vehicle models typically emit more pollutants	Decrease
	Percent of vehicles older than a desired age		Decrease
	Percentage of reused or recycled parts of different types of end-of-life vehicles		Decrease
	Percent of vehicles meeting desired emission standards	To meet desired ambient AQ standards, vehicles need to be meeting emission standards as well	Increase
	Number of vehicles tested as part of a vehicle emissions inspection program		Increase
	Number of vehicles reported as part of TCEQ's Smoking Vehicle Program	Smoking vehicles should be reported to lessen their emission impact	Difficult to determine (more reporting could either mean the public is more involved in getting smoking vehicles fixed or there are more smoking vehicles)
	Use of low-emission diesel fuel versus regular diesel	Directly lessens emissions	Increase
Reduce pollutant emissions from off-road sources by improving operations	Percent of time off-road source spends idling by mode	Extended idling can cause more emissions than start/stop	Decrease
	Percent of transportation-related construction projects implementing dust control measures	Dust control helps minimize particulate matter impact	Increase
	Percent of contractors using ultra-low sulfur fuel	Decreases sulfur emissions	Increase
	Frequency of air quality monitoring and reporting in transportation-related construction	Monitoring can help identify problem areas, and reporting keeps contractors accountable	Increase
	Percent of contractors applying for Texas Emissions Reduction Plan (TERP) grants	Contributes to emissions reduction	Increase

	Annual VMT or freight ton-miles by mode for off-road vehicles	VMT is needed to calculate emissions with current models; increased VMT will increase emissions	Decrease
	Total annual VMT		Decrease
	Size of fleet (number of vehicles) of off-road vehicles and equipment	More vehicles can directly contribute to more emissions	Decrease
	Freight tonnage by off-road mode	Heavier freight may cause more emissions	Decrease
	Freight efficiency (amount of cargo carried versus capacity) of off-road vehicles	Inefficient freight movement may cause more trips to be necessary	Increase
	Number of off-road transit users (i.e. rail)	Increased use of alternate passenger modes could reduce congestion, and alternate modes may emit less than passenger cars	Increase
	Availability of off-road public transit in urban areas		Increase
	Efficiency of shore-side operations at ports and airport operations	Inefficiency may cause more trips or time equipment is operating, increasing emissions	Increase
	Percent of refueling performed between 6am to 10am	More gasoline evaporation occurs between 6 and 10 am	Decrease
Reduce pollutant emissions from off-road sources by improving technology	Average age of off-road vehicle or equipment	Older vehicle models typically emit more pollutants	Decrease
	Percent of off-road vehicles and equipment older than a desired age		Decrease
	Percent of reused or recycled parts of different types of end-of-life off-road vehicles		Decrease
	Percent of off-road vehicles and equipment meeting desired emissions standards	To meet desired ambient AQ standards, vehicles need to be meeting emission standards as well	Increase
	Reduction in emissions from vehicle refueling and evaporation of oil spills	Directly lessens emissions	Increase
	Use of low-emission diesel fuel versus regular diesel		Increase

Goal: Reduce transportation-related greenhouse gas (GHG) emissions			
Objective	**Suggested Indicator**	**Justification**	
		Linkage to Goal	**Desired Direction**
Reduce GHG	Percent of time vehicle spends idling	Extended idling can require more fuel than start/stop	Decrease

emissions from on-road sources by improving operations	Annual VMT for passenger travel by mode	VMT is needed to calculate emissions with current models; increased VMT will increase fuel consumption and GHG emission	Decrease
	Annual VMT of freight or freight ton-miles by mode		Decrease
	Total annual VMT		Decrease
	Total annual VMT per capita		Decrease
	Size of vehicle fleet (number of vehicles)	More vehicles can directly contribute to more emissions and fuel consumption, as well as contribute indirectly like causing more congestion	Decrease
	Freight tonnage on-road	Heavier freight may require more fuel use	Decrease
	Freight efficiency (amount of cargo carried versus capacity) of on-road vehicles	Inefficient freight movement may cause more trips to be necessary	Increase
	Truck percentage of VMT on roadway	Trucks emit more and use more fuel than passenger cars	Decrease (however, a decrease due to more passenger cars is not necessarily desirable)
	Commute mode share percentages for major urban areas	Alternate modes may be more fuel efficient or emit less than passenger cars, and may decrease congestion	Increase in use of alternate modes
	Trips by foot or bicycle		Increase
	Drive alone rate for major urban areas	Carpooling decreases number of vehicles on the road, thereby decreasing fuel consumption and congestion	Decrease
	Number of carpool vehicles estimated from volumes on HOV lanes		Increase
	Occupancy rates of park-and-ride lots	Increased use of alternate passenger modes could reduce congestion, and decrease total fuel use by combining many passenger-trips	Increase
	Number of on-road public transit users (i.e. bus)		Increase
	Availability of on-road public transit in urban areas		Increase
	Percentage of labor force regularly telecommuting	Eliminates vehicle trips	Increase
	Change in level of congestion over time	Increased congestion causes more emissions and fuel use due to vehicle idling	Decrease
	Percent of refueling performed between 6am to 10am	More gasoline evaporation occurs between 6 and 10 am	Decrease
Reduce GHG emissions from on-road	Average vehicle age (on-road)	Older vehicles are typically less fuel efficient	Decrease
	Average fuel efficiency of on-road vehicles	Less fuel efficient vehicles require more gasoline	Increase

sources by improving technology	Gallons of fuel consumed by on-road vehicles, evaluated by fuel type (i.e. gasoline, diesel, alternative fuel, etc.)	The amount of GHGs emitted is directly tied to fuel consumed	Decrease
	Total cost of fuel purchased per year, and average price per year		Decrease, but depends on changes in price
	Availability of alternative fuel	Alternate fuels emit fewer GHGs, and hybrid vehicles use less gasoline than regular vehicles	Increase
	Percent of biofuel targets achieved		Increase
	Percent of vehicles that are hybrid or alternative fuel vehicles (AFVs)		Increase
	Percent of annual vehicles purchased that are hybrids or AFVs		Increase
Reduce GHG emissions from off-road sources by improving operations	Percent of time off-road source spends idling by mode	Extended idling can require more fuel than start/stop	Decrease
	Annual VMT or freight ton-miles by mode for off-road vehicles	VMT is needed to calculate emissions with current models; increased VMT will increase fuel consumption and GHG emission	Decrease
	Total annual VMT		Decrease
	Size of fleet (number of vehicles) of off-road vehicles and equipment	More vehicles can directly contribute to more emissions and fuel consumption	Decrease
	Freight tonnage by off-road mode	Heavier freight may require more fuel use	Decrease
	Freight efficiency (amount of cargo carried versus capacity) of off-road vehicles	Inefficient freight movement may cause more trips to be necessary	Increase
	Number of off-road transit users (i.e. rail)	Increased use of alternate passenger modes could reduce congestion, and alternate modes may use less fuel than passenger cars; total fuel consumption will also decrease with combined passenger-trips	Increase
	Availability of off-road public transit in urban areas		Increase
	Efficiency of shore-side operations at ports and airport operations	Inefficiency may cause more trips or time equipment is operating, increasing emissions	Increase
	Gallons of fuel consumed by shore-side operations at ports and airport operations	The amount of GHGs emitted is directly tied to fuel consumed	Decrease
	Percent of refueling performed between 6am to 10am	More gasoline evaporation occurs between 6 and 10 am	Decrease
Reduce GHG emissions from off-	Average age of off-road vehicle or equipment	Older vehicles are typically less fuel efficient	Decrease
	Average fuel efficiency of off-road vehicles and equipment	Less fuel efficient vehicles require more gasoline	Increase

road sources by improving technology	Gallons of fuel consumed by off-road vehicles and equipment, evaluated by fuel type (i.e. gasoline, diesel, alternative fuel, etc.)	The amount of GHGs emitted is directly tied to fuel consumed	Decrease
	Total cost of fuel purchased per year, and average price per year		Decrease, but depends on changes in price
	Percent of off-road vehicles and equipment that are hybrid or use alternative fuel	Alternate fuels emit fewer GHGs, and hybrid vehicles use less gasoline than regular vehicles	Increase
	Percent of yearly off-road vehicles and equipment purchased that are hybrids or AFVs		Increase

Goal: Reduce the impact of transportation-related emissions on human health			
Objective	**Suggested Indicator**	**Justification**	
		Linkage to Goal	**Desired Direction**
Reduce exposure to poor air quality	Amount of emissions per year of any of the following:□NOx□methane□N2O□CO□CO2 or total GHGs□ozone□particulate matter□non-methane VOCs□SOx□lead□CFCs□MSATs like benzene□Total emissions□□Alternatively, some values could be grouped in an indicator like the Air Quality Index, which includes ozone, CO, and PM.	These pollutants all cause various health problems; severity depends on level of exposure	Decrease for all pollutants
	Total transport-related emissions as a ratio to the national average	Increased emissions or ambient air concentrations increases health risk	As good, or better than, the national average

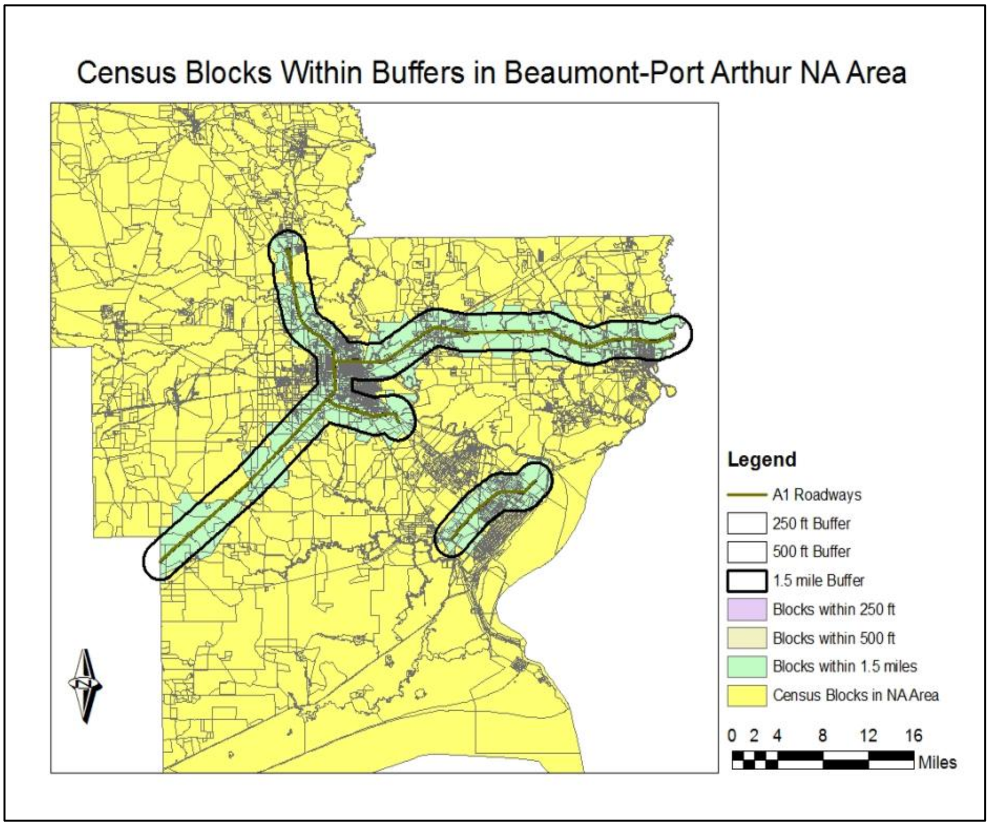
	Average monthly ambient air concentrations of criteria pollutants		Decrease for all pollutants
	Number of non-attainment areas in Texas	Standards are set at levels to protect public health; therefore, not meeting standards may jeopardize public health	Decrease
	Percent of Texas counties classfied as non-attainment		Decrease
	Frequency of air pollution standard violations/exceedances per year		Decrease
	Number of Ozone Action Days	More days of poor air quality increases exposure and health risk	Decrease
	Number of days the Air Quality Index (AQI) is in an unhealthful range (values above 100)		Decrease
	Number of commercial vehicles inspected transporting hazardous material	Accidents could significantly increase exposure to hazardous materials	Depends on whether fewer vehicles transporting hazardous material is desired, or more inspections are desired
	Population exposed to exceedances of urban air quality standards	Indicates how many people may be affected by the air quality in certain areas, and how much of the state population could be affected; 'at-risk' citizens are those especially sensitive to the affects of poor air quality on health	Decrease
	Total population in non-attainment areas		Decrease
	"At-risk" population in non-attainment areas (i.e. children, the elderly, asthmatics, people with heart or lung disease, and the very active or those outdoors extensively)		Decrease
	Total population living within a certain distance of a freeway	Living near a freeway significantly increases exposure to transportation-related emissions	Decrease
	"At-risk" population living within a certain distance of a freeway		Decrease

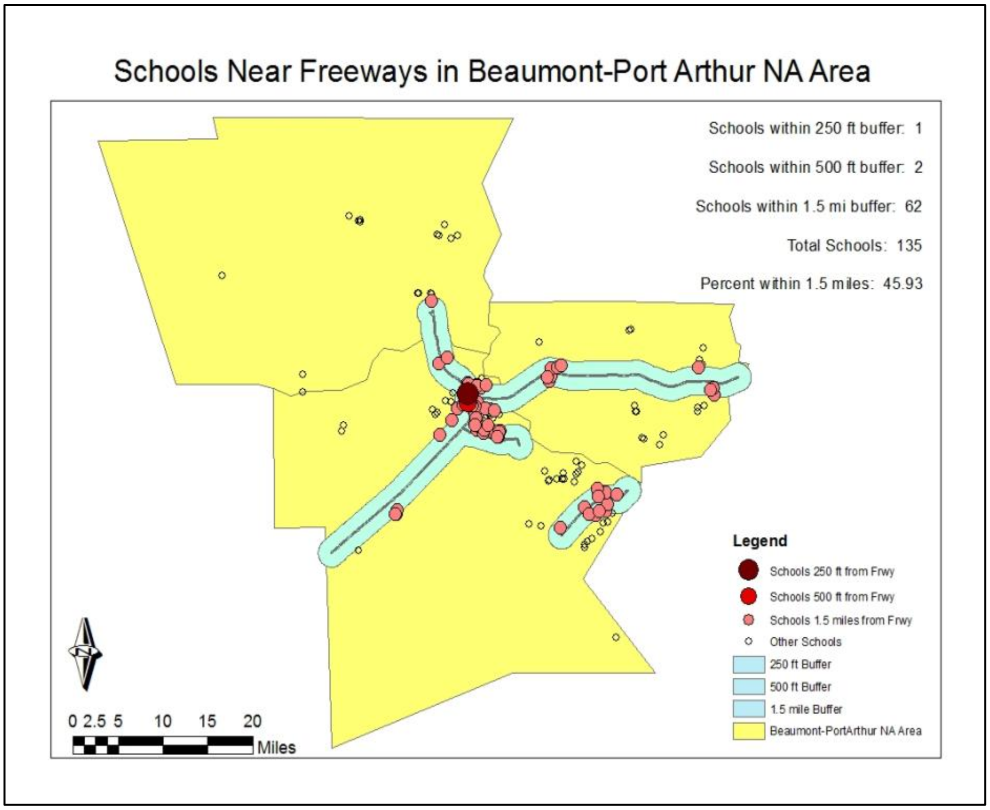
Goal: Improve agency monitoring and response to air quality problems			
Objective	**Suggested Indicator**	**Justification**	
		Linkage to Goal	**Desired Direction**
Reduce TxDOT energy use in	Percent of warning lights/signs in the TxDOT fleet that are LED (as opposed to incandescent)	LED bulbs are more energy efficient than incandescent	Increase

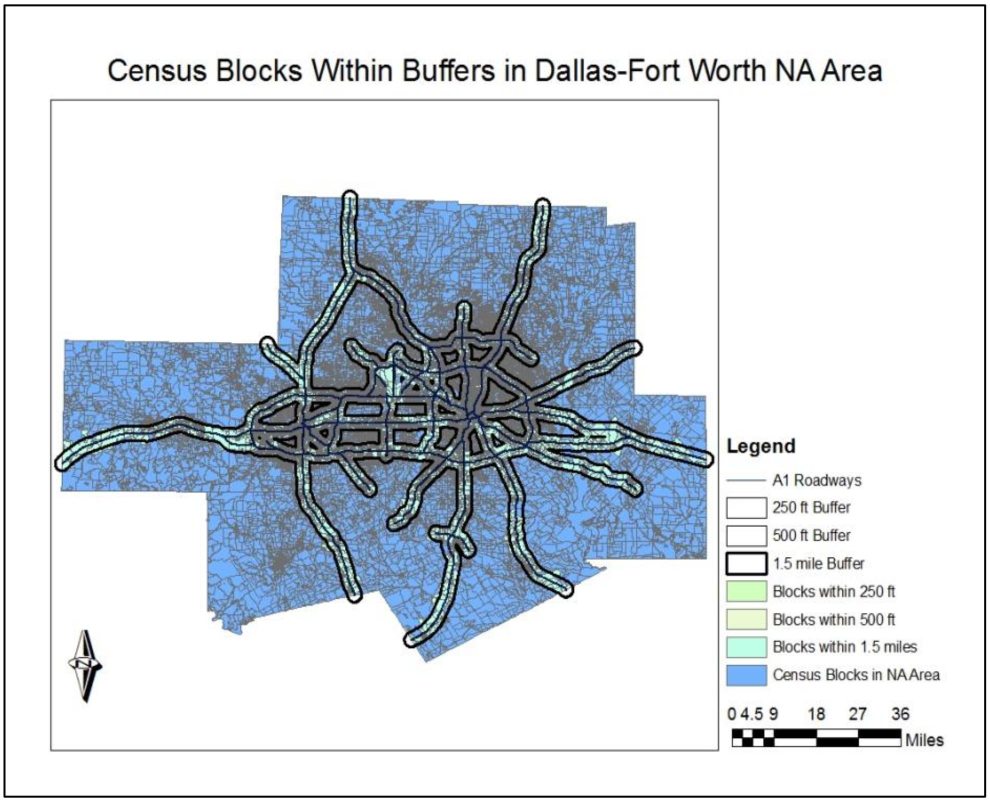
the transportation field	Frequency of conversion from incandescent to LED of warning lights/signs in the TxDOT fleet		Increase
	Percent of traffic services (traffic signals, street lights, etc.) that are LED (as opposed to incandescent)		Increase
	Frequency of conversion from incandescent to LED of traffic services (traffic signals, street lights, etc.)		Increase
	Percent of lights and signs powered by solar energy	Solar energy is self-sustaining	Increase
	Percent time spent idling for TxDOT vehicles/equipment	Extended idling can use more fuel than start/stop	Decrease
	VMT for TxDOT vehicles/equipment per year	VMT is needed to calculate emissions with current models; increased VMT will increase fuel consumption and GHG emission	Decrease
	Freight-tons for TxDOT vehicles/equipment per year	Heavier freight may require more fuel use	Decrease
	Size of TxDOT fleet	More vehicles can directly contribute to more emissions and fuel consumption	Decrease
	Average age of TxDOT fleet	Older vehicles are typically less fuel efficient	Decrease
	Average fuel efficiency of TxDOT fleet, or by vehicle/equipment type	Less fuel efficient vehicles require more gasoline	Increase
	Percent of ROW mowing performed on Ozone Action Days	Reduce ozone output on days when levels are already unhealthy	Decrease
	Reduction in ROW mowing	Less mowing leads to less fuel consumption	Increase
Increase emphasis on emission problems through TxDOT employee actions	Number of employee training sessions to educate on reducing air pollution, either at work or at home	Ways TxDOT can directly encourage good practice from employees in an effort to reduce emissions	Increase
	Number (or presence) of employee requirements for operating state vehicles that pertain to emission reduction		Increase
	Incentive programs to encourage employee reduction of emissions		Increase
	Use of flexible or compressed work schedules, or telecommuting for TxDOT employees	Can reduce trips and/or congestion	Increase
	Percent of employees taking public transit, walking, biking, carpooling, or vanpooling	Use of alternate modes can reduce congestion, use less energy, and emit less	Increase

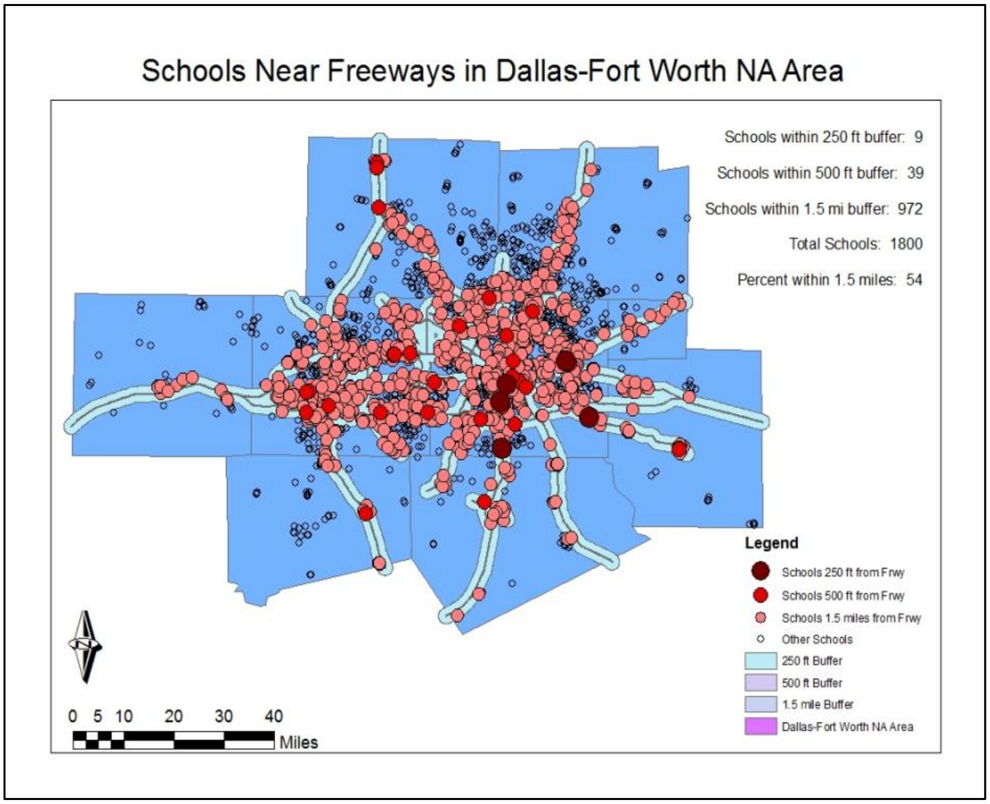
	Amount of priority parking provided for employees participating in car- and vanpools	Encourages employees to carpool, thereby reducing congestion, fuel use, and emissions	Increase
	Percent of this priority parking occupied		Increase
Promote public outreach	Number of public outreach programs per month or year	Way to educate the public on good practices	Increase
	Percent of citizens reached by education and outreach programs	How many citizens are receiving education	Increase
	Customer perception of satisfaction with an outreach program	How useful education efforts are to citizens in aiding them to reduce personal emissions	Increase
	Frequency of communication to the public	Helps to inform public and increase accountability	Increase

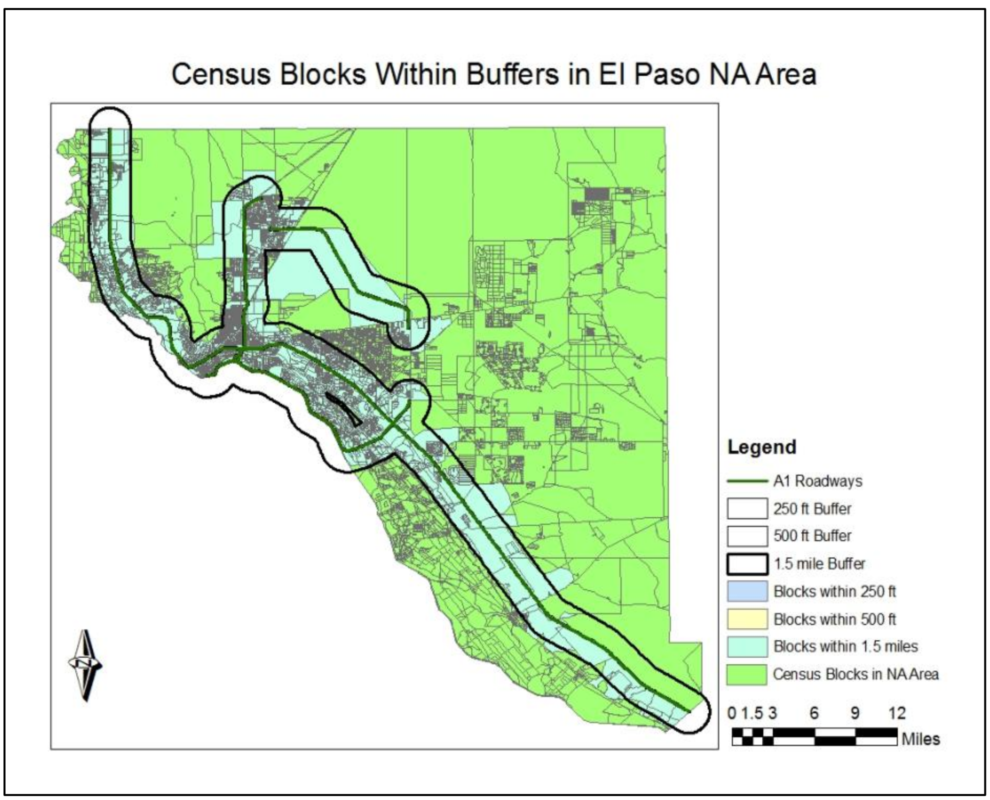
APPENDIX G: GIS MAP OUTPUT FOR FREEWAY PROXIMITY MEASURES

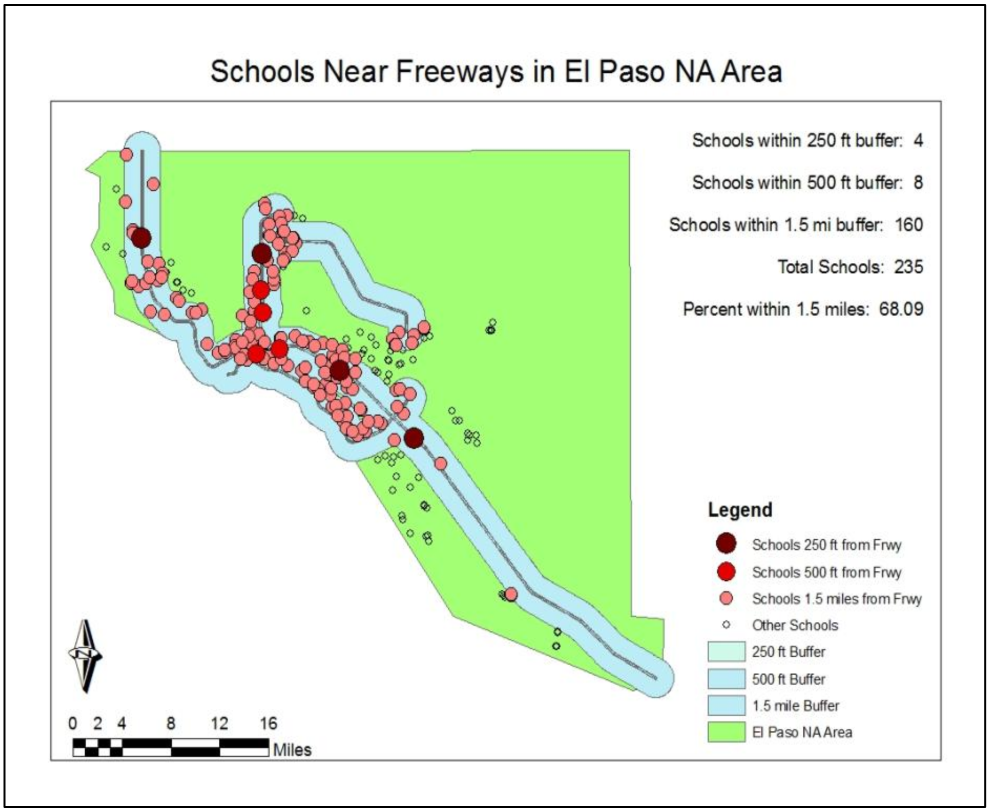


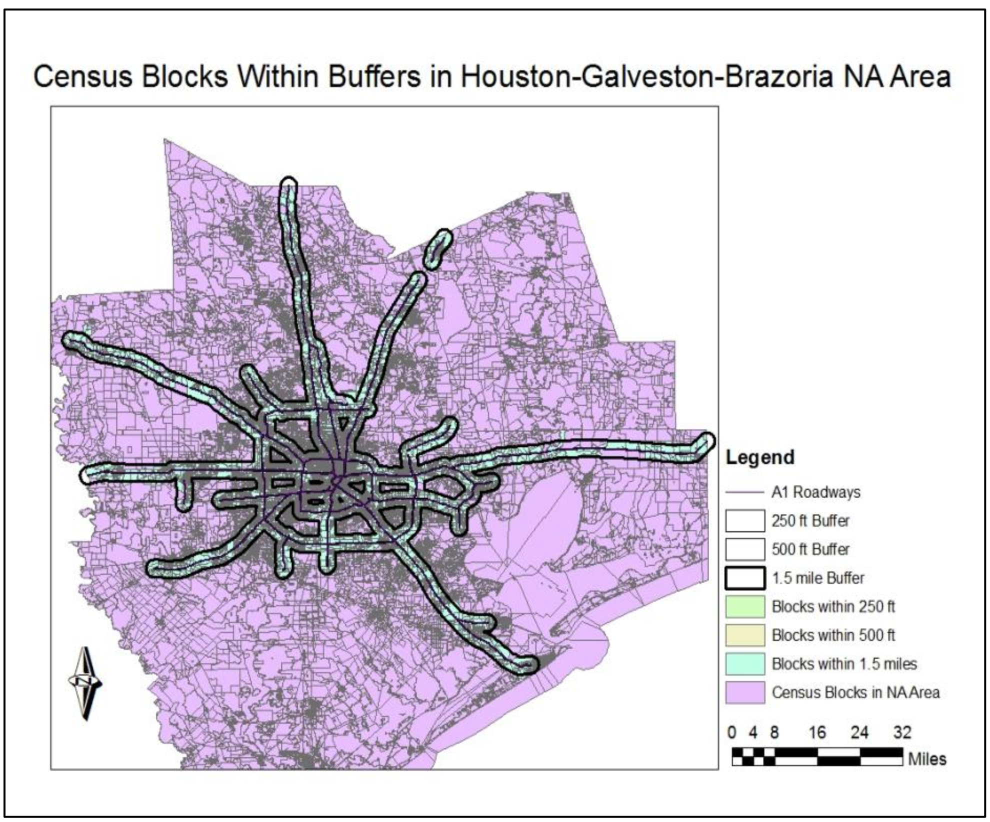

Schools Near Freeways in Beaumont-Port Arthur NA Area
Schools within 250 ft buffer: 1
Schools within 500 ft buffer: 2
Schools within 1.5 mi buffer: 62
Total Schools: 135
Percent within 1.5 miles: 45.93
Legend
Schools 250 ft from Frwy
Schools 500 ft from Frwy
Schools 1.5 miles from Frwy
Other Schools
250 ft Buffer
500 ft Buffer
1.5 mile Buffer
Beaumont-PortArthur NA Area
0 2.5 5 10 15 20
Miles

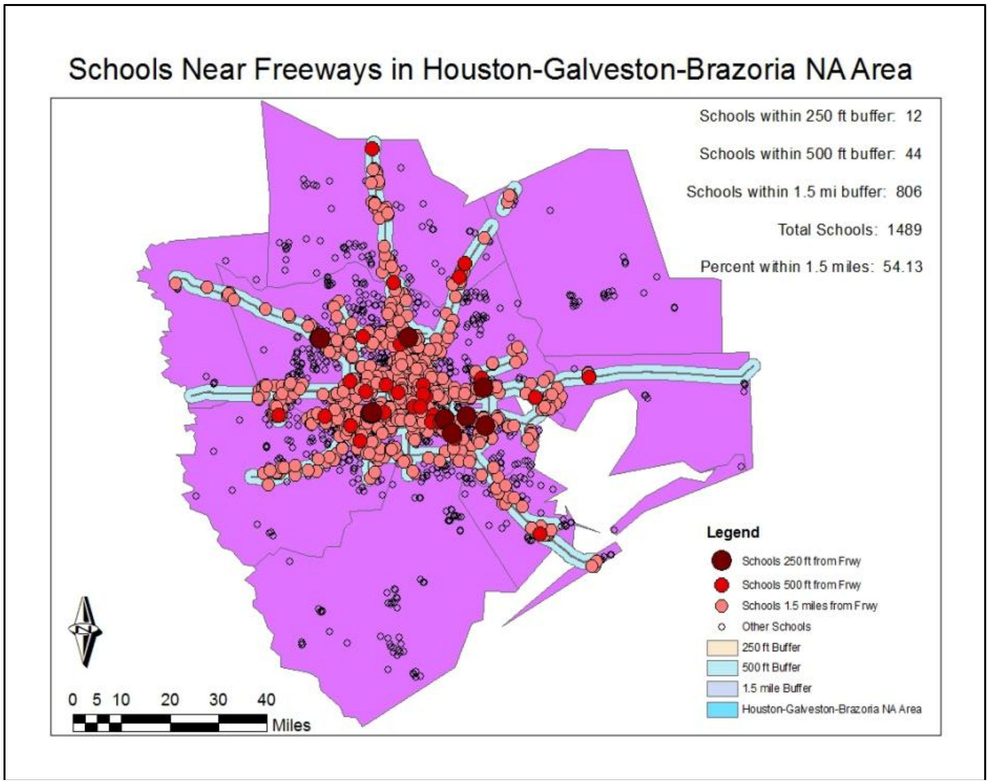

Census Blocks Within Buffers in Dallas-Fort Worth NA Area
Legend
A1 Roadways
250 ft Buffer
500 ft Buffer
1.5 mile Buffer
Blocks within 250 ft
Blocks within 500 ft
Blocks within 1.5 miles
Census Blocks in NA Area
0 4.5 9 18 27 36
Miles


Schools Near Freeways in Dallas-Fort Worth NA Area
Schools within 250 ft buffer: 9
Schools within 500 ft buffer: 39
Schools within 1.5 mi buffer: 972
Total Schools: 1800
Percent within 1.5 miles: 54
Legend
Schools 250 ft from Frwy
Schools 500 ft from Frwy
Schools 1.5 miles from Frwy
Other Schools
250 ft Buffer
500 ft Buffer
1.5 mile Buffer
Dallas-Fort Worth NA Area
0 5 10 20 30 40
Miles


Census Blocks Within Buffers in El Paso NA Area
Legend
A1 Roadways
250 ft Buffer
500 ft Buffer
1.5 mile Buffer
Blocks within 250 ft
Blocks within 500 ft
Blocks within 1.5 miles
Census Blocks in NA Area
0 1.5 3 6 9 12
Miles


Schools Near Freeways in El Paso NA Area
Schools within 250 ft buffer: 4
Schools within 500 ft buffer: 8
Schools within 1.5 mi buffer: 160
Total Schools: 235
Percent within 1.5 miles: 68.09
Legend
Schools 250 ft from Frwy
Schools 500 ft from Frwy
Schools 1.5 miles from Frwy
Other Schools
250 ft Buffer
500 ft Buffer
1.5 mile Buffer
El Paso NA Area
0 2 4 8 12 16
Miles


Census Blocks Within Buffers in Houston-Galveston-Brazoria NA Area
Legend
A1 Roadways
250 ft Buffer
500 ft Buffer
1.5 mile Buffer
Blocks within 250 ft
Blocks within 500 ft
Blocks within 1.5 miles
Census Blocks in NA Area
0 4 8 16 24 32
Miles


Schools Near Freeways in Houston-Galveston-Brazoria NA Area
Schools within 250 ft buffer: 12
Schools within 500 ft buffer: 44
Schools within 1.5 mi buffer: 806
Total Schools: 1489
Percent within 1.5 miles: 54.13
Legend
Schools 250 ft from Frwy
Schools 500 ft from Frwy
Schools 1.5 miles from Frwy
Other Schools
250 ft Buffer
500 ft Buffer
1.5 mile Buffer
Houston-Galveston-Brazoria NA Area
0 5 10 20 30 40
Miles

APPENDIX H: TABULAR EMISSIONS STANDARDS FOR HEAVY-DUTY VEHICLES

Emissions Standards for Heavy-Duty Highway Spark-Ignition Engines and Compression-Ignition Engines, and Urban Buses

Year	HC (g/bhp-hr)			NMHC (g/bhp-hr)		NMHC + NOx (g/bhp-hr)		NOx (g/bhp-hr)		PM (g/bhp-hr)			CO (g/bhp-hr)			Idle CO (% exhaust gas flow)	
	Spark-Ignition		Compression-Ignition/Urban Buses	Spark-Ignition	Compression-Ignition/Urban Buses	Spark-Ignition	Compression-Ignition / Urban Buses	Spark-Ignition	Compression-Ignition/Urban Buses	Spark-Ignition	Compression-Ignition	Urban Buses	Spark-Ignition		Compression-Ignition/Urban Buses	Spark-Ignition	Compression-Ignition/Urban Buses
	<=14,000 lbs GVW	>14,000 lbs GVW											<=14,000 lbs GVW	>14,000 lbs GVW			
1974-78	-		-	-	-	-	16	16	-	-	-		40		40	-	-
1979-84	1.5		1.5				10	10					25		25		
1985-86	1.9		1.3			10.6	-	-	10.7				37.1		15.5		
1987	1.1	1.9											14.4	37.1		0.5	
1988-89						6					0.6					-	0.5
1990									6							0.5	
1991-93						5			5.0 [ABT]		0.25 [ABT]	0.1					
1994-95											0.1 [ABT]	0.07					
1996-97												0.05					
1998-2003						4			4.0 [ABT]			0.1					
2004			-				2.4 (or 2.5 with a limit of 0.5 on NMHC) [ABT]		-		0.1	0.05					
2005-06						-		1									
2007					0.14				0.2		0.01						
2008+	-			0.14				0.2		0.01	0.01		14.4				