



Effect of and Alternatives to Restricting Operation of Construction Equipment to Improve Regional Air Quality

Texas Natural Resource Conservation Commission (TNRCC) rules, now withdrawn, were to affect the Texas Department of Transportation (TxDOT) by placing restrictions on construction equipment activity. One rule, which was to become effective in 2005, sought to reduce ozone formation by limiting the amount of oxides of nitrogen (NO_x) produced by heavy-duty diesel equipment in the early morning hours. The rule restricted the use of equipment $\geq$ 50 horsepower during the morning hours of the ozone season at construction sites in the Dallas/Fort Worth (DFW) and Houston/Galveston (HG) nonattainment areas. Exemptions to this rule were to be filed with TNRCC by May 31, 2002.

This project reviewed TNRCC's analysis, evaluated potential project cost and schedule impacts, assessed alternative emission control technologies, and evaluated the impacts of work zone lane closures for on-road emissions.

What We Did . . .

Using a three-tiered approach, researchers identified other restrictions on operating construction equipment across the country. First they interviewed the Environmental Protection



Figure 1. A major freeway reconstruction in an urban area

Agency's (EPA) national offices in Ann Arbor, Michigan, and staff from selected state departments of transportation. TNRCC staff involved in photochemical modeling, emission inventory, and off-road mobile sources were also interviewed to assess the construction equipment restriction rule. Concurrent with the interviews, researchers performed a critical analysis of associated sections within the DFW and HG State Implementation Plan (SIP) Attainment Demonstration documents.

The research team applied empirical data for heavy-highway construction site

emissions to 2000 construction activity reported by district staff for the DFW and HG nonattainment areas. They extracted diesel-powered equipment activity recorded at heavy-highway construction sites previously collected for TxDOT Research Project 0-1745, Air Quality Impacts of Highway Construction and Scheduling. They applied these diesel-only emissions to major or minor project sites. Results of this empirically based analysis were then compared to estimates generated by TNRCC.

To determine potential impacts on project cost and



scheduling due to the construction equipment restriction rule, researchers conducted a literature review and interviews with TxDOT staff and heavy-highway contractors in the DFW and HG nonattainment areas. Highway construction work was grouped into five general project types for analysis. Various work schedule alternatives (WSAs) that contractors could implement in response to the rule were assessed for the five project types. Based on these WSAs and the project types, participants estimated project cost and schedule impacts for the WSA as a percentage of the expected cost. Using those estimates in a matrix format, a single estimate of project cost and schedule increases was then derived.

Researchers conducted a literature review on possible alternative emission control technologies available for heavy-duty diesel engines. Cost-effectiveness was calculated for selected technologies, including selective catalytic reduction (SCR), then compared to NOx reduction benefits of the construction equipment restriction rule.

Finally, the research team evaluated potential impacts to road user cost and emissions resulting from possible work zone lane closures. Using the QUEWZ-98 model and a post-processing procedure, 161 scenarios were analyzed, covering three average daily traffic (ADT) categories, two to five lane same-direction sections, and three peak period and five off-peak period schedules.

What We Found . . .

Around the Country

No SIP-related construction restriction programs were identified outside Texas, current or proposed. Several construction upgrade incentive programs, and a few project specific construction restrictions (e.g., the Boston tunnel



Figure 2. Early morning elevated concrete placement

project), were identified. All project specific construction restrictions were very limited in scope and application, and typically based on traffic impact rather than air quality. Most importantly, none were part of a SIP program. Construction equipment upgrade incentive programs identified, like the Carl Moyer Program in California, may provide contractors a means to develop exemption plans while sharing cost with the state.

Critical Review of Analysis and Documentation

The process of developing industry-sector emissions and photochemical modeling is an art as much as a science. Generating and distributing emission sources and determining the impacts or effectiveness of proposed control strategies require numerous assumptions. The methodology framework used by TNRCC staff to estimate construction emissions seemed appropriate; however, the spatial allocation of heavy-highway sector emissions could be improved.

TNRCC's consultant produced a viable method for estimating local-level equipment populations and associated activity. These factors revealed that default NONROAD values for statewide population and

activity result in more than three times the emissions overestimation developed by EPA. TNRCC's analysis more accurately represented construction fleets and activities in HG and DFW and greatly reduced the construction emissions inventory.

The local equipment populations and activity results from HG, factored through surrogate variables, estimated the equipment population and activity in DFW. However, the surrogates and assumptions used in Houston were applied to DFW with no validation.

Use of Empirical Construction Site Emissions Data

Empirically based construction site emissions data, used as a sketch-planning tool, conservatively estimate the heavy-highway NOx emissions. Inventories and activity data derived locally provide a greater degree of accuracy in the emission estimate. Also, repeated use of the NONROAD model provides analysis techniques for fleet turnover and other effects not reflected in empirical data.

Potential Project Cost and Schedule Impacts

Analysis of the survey responses and comments provided by TxDOT



and contractor participants regarding the effect of the construction equipment restriction rule yielded the following conclusions:

- Limited historical data are available to support a cost-impact evaluation; all data are drawn from professional experience of those most familiar with highway construction operations in nonattainment areas.
- Reduced labor productivity and quality, coupled with higher labor wage rates, traffic control, construction lighting, and safety costs, are expected to increase TxDOT project costs and schedules.
- Lower morale and increased safety concerns for TxDOT and contractor personnel may further affect TxDOT project costs and schedules.
- Contractors favor work schedules providing continuous operation for crews, as reflected in the cost and schedule impacts.
- The average overall project duration increase anticipated for that period the rule is in effect is 6 to 12 percent in HG and 5 to 28 percent in DFW.
- The anticipated average overall construction cost increase anticipated during time periods the rule is in effect (including the costs of extended schedules) is between 8 and 16 percent in HG, and between 4 and 32 percent in DFW. These percentages compare favorably with initial TNRCC cost assessments of 15 to 20 percent of TxDOT's annual letting amounts.

The cost of this rule to TxDOT is estimated to be \$116 million annually, or approximately \$350,000 to \$550,000 per ton NOx reduced. This annual cost is equivalent to any one of the following:

- 72.5 million gallons of gasoline at \$1.60 per gallon,

- fueling TxDOT's entire on-road and off-road fleet for 8.3 years ,
- eighth-largest district construction expenditures in FY 00, or
- nearly equivalent to the combined construction expenditures of Brownwood, San Angelo, and Abilene Districts in FY 00.

Alternative Emission Control Technologies

Through the equipment operating restrictions, TNRCC expects an estimated 21 and 13 percent NOx emission reduction from the construction industry in the HG and DFW areas, respectively.

Alternative control measures for construction projects, such as diesel engine emission controls, would potentially allow equipment to operate during normal working hours and still provide NOx emission reductions. TxDOT may pay \$350,000 to \$550,000 per ton NOx reduced as a result of the rule. In comparison, emission control devices are conservatively estimated to cost four to ten times less. Review and assessment of diesel engine emissions indicate that after-treatment emission controls would range from \$24,000 to \$55,000 per ton NOx reduced when implemented across the entire fleet, and \$80,000 to \$120,000 per ton NOx reduced if such controls are only partially implemented.

Alternative control measures potentially offer similar or greater NOx reduction benefits for less money. However, the after-treatment approach to emission control presents unique challenges, such as: limited commercial availability of NOx after-treatment devices for a broad range of engine horsepower; long-term reliability and maintenance; reduced fuel efficiency; and the evolving nature of emission control technology. The primary benefit of after-treatment use is the potential for greater NOx reductions sooner. Emission

benefits from emission control devices on heavy-highway equipment occur year-round, producing even greater reductions.

On-Road Emissions Resulting from Lane Closures

Researchers developed a post-processing procedure to overcome limitations (treatment of diverted traffic and speed reductions with no queuing) of QUEWZ-98's current emissions module. The evaluation generated tables and graphs that will aid TxDOT construction staff in the DFW and HG nonattainment areas. These tools can generalize road user cost and emissions impacts (VOC, CO, and NOx) from lane closures for a variety of work schedules. If specific cases require analysis, QUEWZ-98 and the post-processing procedure can be used for evaluation.

The Researchers Recommend . . .

Many recommendations formed from this project require additional investigation. They may be implemented separately or as combined programs. The recommendations are:

- Cooperatively work with construction firms to minimize possible construction schedule delays resulting from the rule.
- Investigate developing an equipment upgrade incentive program in Texas.
- Investigate providing NOx contract incentives for operating cleaner-burning equipment.
- Investigate adding contractor use of clean-burning equipment as a pre-qualification requirement.
- Create a database of clean/super-clean construction equipment used on TxDOT projects.
- Update the QUEWZ-98 model to address emissions analysis limitations.



For More Details . . .

The research is documented in the following reports:

Report 4190-3, Potential Cost and Schedule Impact of Texas Natural Resource Conservation Commission's Proposed Rule Restricting the Use of Construction Equipment

Report 4190-5, Potential Emission Reduction Effects of Alternative Construction Equipment Control Measures

Report 4190-6, Assessment of Impacts from Construction Equipment Restrictions in Select Texas Nonattainment Areas

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To obtain copies of these reports, contact Dolores Hott, Texas Transportation Institute, Information and Technology Exchange Center, (979) 845-4853, or e-mail d-hott@tamu.edu. See our on-line catalog at <http://tti.tamu.edu>.

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The research established the impacts of highway construction activities in Texas nonattainment areas and evaluated numerous mitigation measures. The research concluded that alternative emission controls on construction equipment were more beneficial in terms of emission reductions and cost than altering construction activity schedules. This data will be used in State Implementation Plan (SIP) development, which will enhance SIP development and keep TxDOT projects on schedule.

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