Intelligent Transportation Systems Field
Operational Test
Cross-Cutting Study

Emissions Management Using ITS Technology

September 1998

Prepared for:
U.S. Department of Transportation
Federal Highway Administration
Washington, D.C.

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Technical Report Documentation Page

1. Report No. FHWA-JPO-99-039	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle INTELLIGENT TRANSPORTATION SYSTEMS FIELD OPERATIONAL TEST CROSS-CUTTING STUDY EMISSIONS MANAGEMENT USING ITS TECHNOLOGY		5. Report Date September 1998 6. Performing Organization Code Booz•Allen & Hamilton Inc.
7. Author(s) Keith Jasper		8. Performing Organization Report No.
9. Performing Organization Name and Address Booz•Allen & Hamilton Inc. 8201 Greensboro Drive Suite 609 McLean, Virginia 22102		10. Work Unit No. (TRAIS) 11. Contract or Grant No. DTFH61-94-C-00207
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highways Administration Intelligent Transportation Systems Joint Program Office 400 Seventh Street, SW, Room 3422 Washington, DC 20590		13. Type of Report and Period Covered Cross-Cutting Study November 1997 – September 1998 14. Sponsoring Agency Code HVH-1
15. Supplementary Notes Contracting Officer's Technical Representative (COTR) - Joe Peters, Room 3416		

16. Abstract

Emissions Management Using ITS Technology report summarizes and interprets the results of three Intelligent Transportation Systems (ITS) Field Operational Tests (FOTs) that evaluated the use of emerging technologies to help authorities measure emissions and develop strategies to help control them. Two of these tests use similar technologies employing a remote infrared sensing device to analyze the carbon monoxide content of the exhaust of a vehicle. The other test used Light Detection and Ranging (a technology similar to radar) to measure the amount and character of pollution in the air. The FOTs considered in this report are: LIDAR, TDM/ED and R-TED. Institutional issues were not significant in these tests. The report findings are organized in the categories of impact, user response, technical lessons learned, institutional challenges and resolutions, and cost to implement. This report highlights the successes and problems these tests encountered while attempting to develop the technologies appropriate to measuring and reacting to vehicle emissions.

17. Key Words	18. Distribution Statement
Emissions Management, ITS Technologies, ITS Impacts, FOTs, Field Operational Tests, Cross-Cutting report	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	20	

Form DOT F 1700.7 **(8-72)** Reproduction of completed page authorized

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EXECUTIVE SUMMARY

The effects of poor air quality and excessive pollution have long been a concern of government agencies. As agencies struggle to control air quality in their jurisdictions, managing vehicle emissions has become an area of vital interest. Emissions management is the process of trying to control the amount and character of the gases and particles emitted by vehicles and industrial processes. Studies have indicated that as few as 10 percent of the vehicles can contribute as much as 50 percent of the air pollution in a metropolitan area. Authorities try to manage vehicle emissions by regularly testing vehicles and by attempting to reduce traffic congestion. This report summarizes and interprets the results of three Intelligent Transportation Systems (ITS) Field Operational Tests (FOTs) that evaluated the use of emerging technologies to help authorities measure emissions and develop possible strategies to help control them.

Two of these tests use similar technologies employing a remote infrared sensing device to analyze the carbon monoxide content of the exhaust of a vehicle. The other test used Light Detection and Ranging (a technology similar to radar) to measure the amount and character of pollution in the air.

The two remote sensing device tests used the information collected to provide feedback to drivers to encourage them to have their vehicles tuned or repaired. Authorities used the information from the one test to examine vehicle emissions testing policy. Personnel in another test believe that the technology has a good potential for use in pollution source and dispersion modeling.

The user response to the two remote sensing tests was favorable. Drivers preferred the less intrusive method of testing their vehicles and did not have serious qualms about the method invading their privacy.

The remote sensing tests had few technical problems and that technology can be deployed without much additional development. The Light Detection and Ranging technology was considered a prototype and would require significant further testing and development before it could be put to practical use.

Institutional issues were not significant in these tests. The test partnerships worked well, in spite of the combination of private and public partners. One of the remote sensing tests addressed several issues before starting the test. This test partners included the state and the local air quality boards to encourage a good relationship and the partners developed possible solutions to the anticipated problem of "high polluters." Both remote sensing tests were concerned about the legal ramifications of capturing vehicle license plate information. The tests obtained legal opinions to assure themselves that this would not be a problem. The two remote sensing tests also conducted strong public awareness campaigns to promote knowledge and understanding of these tests.

This report highlights the successes and problems these tests encountered while attempting to develop the technologies appropriate to measuring and reacting to vehicle emissions.

REPORT BACKGROUND

In 1991, the U.S. Department of Transportation (US DOT) initiated a new program to address the needs of the emerging ITS field. This program solicited and funded projects, called FOTs. The tests were sponsored and supported by several administrations of the Department, including the Federal Highway Administration (FHWA), the Federal Transit Administration (FTA), and the National Highway Traffic Safety Administration (NHTSA).

The FOTs demonstrated potentially beneficial transportation products, technologies, and approaches. The FOTs implemented these products, technologies, or approaches on a limited scale under real-world operational conditions. These tests were an interim step bridging the gap between conventional research and development (that formed the idea), and full-scale deployment (that would see widespread use of the idea). FOTs typically included a local or regional transportation agency, as well as the FHWA, as partners in the project. The partners often included private sector providers of the equipment, systems, and services interested in demonstrating their idea. The FOTs concentrated on user service areas described in the *National ITS Program Plan that* needed a "proof of concept" in order to achieve deployment goals.

A fundamental element of each test was an independent, formal evaluation. The evaluation was designed to produce a final report that detailed the test's purpose, methods, and findings. The evaluation aspect of the test intended to assess whether the product, technology or approach provided effective solutions at acceptable levels of cost, schedule, and technical risk.

As the sponsoring organization and a partner in many of the FOTs, the FHWA played a central role. FHWA supported the tests by providing a standardized set of evaluation guidelines and by helping coordinate and promote the relationships among test partners. The FHWA also acted as the communications clearinghouse collecting reviewing, and disseminating information about the tests.

Among the more than 80 FOTs, several tests encompassed the same or similar areas of interest. The FHWA has prepared several "cross-cutting" studies that compare or synthesize the findings of multiple tests within a particular area of interest. The purpose of this series of studies is to extract from the separate tests the common information and lessons learned that are of interest ITS practitioners and that could improve the testing and deployment of future applications of the subject technology.

This study is one of the series described above. It focuses on the topic of Emissions Management using ITS Technologies.

INTRODUCTION

Air quality and pollution have been of significant concern to local, state, and federal agencies as well as the general public for many years. The effects of poor air quality in several major metropolitan areas have repeatedly received publicity. Government officials have long struggled with the problem of how to improve air quality. Legislative efforts, such as the Clean Air Act and its amendments as well as similar state legislation, are only a few of the visible manifestations of these concerns.

Although there are many sources of pollution, one source that most people encounter every day is from vehicles used in transportation. Numerous studies have shown that personal transportation vehicles (cars and light trucks) contribute significantly to pollution. Several studies have shown that a small percentage of vehicles can sometimes contribute as much as half of the vehicle emissions in a metropolitan area. Other studies have shown that congested traffic conditions result in more rapid build-up of pollution than do free-flow conditions.

Emissions Management is the process of trying to control the amount and character of the gases and particles emitted by vehicles and industrial processes. This management effort usually falls to a local or regional government agency as it tries to comply with the air quality guidelines established by the Environmental Protection Agency (EPA).

To improve air quality, numerous regional and state jurisdictions have attempted to manage vehicle emissions. The most common method has been through regular emissions testing of vehicles. A regular testing program can identify "high polluting" vehicles and provide incentives to the owners to have them repaired.

There are several drawbacks to a testing program, however. First, jurisdictions usually test vehicles using idle emissions tests. These tests require the motorist to drive the vehicle to a specially equipped location (a repair garage or testing center) to have the test performed. Testing at these centers means additional miles driven and an added expense for the owner. Second, most testing programs require all vehicles (or all vehicles over a certain age) to be tested. Since a small portion of vehicles is often responsible for a large portion of vehicle emissions, testing all vehicles is not efficient.

If authorities could find a way to identify the vehicles that are "high polluters," testing and repair efforts could be concentrated on this small portion of the fleet. Such a method would use resources more effectively than the "test all vehicles" approach. Two of the FOTs examined in this report evaluated technologies that advance this more efficient approach.

Another way in which jurisdictions have attempted to reduce pollution is to manage traffic congestion. The emission effects of idling or slow moving vehicles are often readily observed but difficult to quantify. Another of the tests examined in this report evaluated a technology for assessing the cumulative emissions of traffic to compare congested conditions to free-flow conditions.

This report was prepared using material gathered as part of Booz•Allen & Hamilton's work to provide evaluation oversight support of ITS FOTs. This material includes published and unpublished reports prepared by the test personnel and evaluators as well as information gathered in meetings and conversations with test personnel. Booz•Allen was not directly involved in the conduct of the tests and did not collect additional data. The reports prepared by the test personnel and evaluators present the findings, results, and conclusions of the tests themselves. This report interprets the results of a group of tests that have a common theme in an attempt to extract lessons that cut across the group of tests. Because it draws from the results of the tests as a group, this report may offer lessons and conclusions that are not found in the material from the individual tests.

FOTs Included In This Analysis

This report draws its findings from three ITS FOTs that evaluated emerging technologies:

- **Evaluating Environmental Impacts of Intelligent Vehicle Highway Systems (IVHS) using Light Detection and Ranging (LIDAR) Technology**—conducted during summer of 1994 in the Minneapolis-Saint Paul Metropolitan area
- **Travel Demand Management/Emissions Detection (TDM/ED)**—conducted during spring of 1995 in Ada County (Boise), Idaho
- **Real-Time Vehicle Emissions Detection (R-TED)**—conducted during 1996 in Denver, Colorado

All three of these tests used advanced technologies to measure vehicle emissions in the field. The LIDAR test measured the aggregate effects of vehicle traffic, whereas the TDM/ED and R-TED tests measured the emissions of individual vehicles.

LIDAR

The LIDAR FOT demonstrated and evaluated the use of light detection and ranging technology in monitoring air quality. In the words of a preliminary evaluation, "The primary goal of this operational test was to determine the usefulness of LIDAR technology as an air quality monitoring tool." The test attempted to determine "whether a quantitative relationship existed between the LIDAR measurements and pollutant concentrations…, and if so, under what conditions."

LIDAR technology operates in a manner similar to radar, except that the emitted signal is a laser beam rather than a radio wave. The LIDAR "gun" sends out pulses of laser light in a specific direction. Suspended aerosol particles (including soot emitted by vehicles, road and tire dust, condensed hydrocarbons, and background particles carried by the wind) in the path of the beam reflect some of the light to the instrument. The instrument does not respond directly to gases such as carbon monoxide. The equipment collects the reflection using a telescope and focuses it onto a sensitive photodetector. The equipment resolves the spatial distribution of particles by measuring the time it takes for the reflected light to reach the detector. The system can produce two-and three-dimensional maps of the reflected signal by scanning the laser through a sequence of angles.

Test personnel installed the LIDAR system and a group of standard air quality monitoring devices at public events expected to produce significant amounts of traffic and, consequently, vehicle emissions. The LIDAR equipment scanned the area above the expected traffic flow. Test personnel placed the air quality monitoring devices in the path of the LIDAR beam near the location of the expected traffic flow. These devices independently measured several air quality indicators to provide confirmation of the LIDAR readings.

TDM/ED

The TDM/ED ITS FOT assessed the usefulness of a Remote Sensing Device (RSD) of vehicle emissions during normal driving conditions. Among other goals, the test evaluated the effectiveness of incentives for voluntary repairs of "high-emitting" vehicles. The test also evaluated the technical and economic feasibility of using RSD technology to enhance the existing idle emissions testing program of Ada County.

The RSD was an infrared sensor capable of reliably analyzing the hydrocarbon, carbon dioxide (CO_2), and carbon monoxide (CO) content of the exhaust of the vehicle. The RSD did not measure oxides of nitrogen nor particulate matter. The device compared the ratio of CO to CO_2 and of hydrocarbons to CO_2 in front of the moving vehicle to the same ratio behind the vehicle. The tested system included a License Plate Reader (LPR) to obtain information to associate the emissions reading of the vehicle to its owner. The system also included radar equipment to measure the acceleration state of the vehicle at the moment of testing. The test used the RSD to monitor emission levels of vehicles as they drove under normal conditions. Test personnel used the results of the field monitoring to compare the emission levels of regularly tested autos (registered in Ada County) to those not tested. They also used the results to determine the feasibility of supplementing or replacing the Ada County idle emissions testing program. The test results did not define the CO emission levels for "clean" or "high emitting."

R-TED

The R-TED FOT used an active infrared emissions sensor similar to the equipment used in the TDM/ED test. The goal of the test was to promote the immediate delivery, to the driver of the vehicle, of data supplied by the remote sensing device. Test planners hypothesized that the availability of this information would help reduce fuel consumption, increase vehicle operating efficiency, and improve air quality. The test defined several objectives to support this goal.

- Develop an on-demand emissions information tool to provide real-time vehicle emissions information to the motorist
- Educate the public about the air quality and cost benefits of keeping their vehicles well-tuned
- Encourage people to voluntarily have their vehicles tested
- Demonstrate the usefulness and public acceptance of the R-TED approach to reducing harmful emissions.

The test installed a RSD and a Variable Message Sign (VMS) on a freeway off-ramp leading to a major Denver arterial roadway near the center of the city. As a vehicle passed the RSD, the infrared beam of the detector monitored its exhaust emissions. The measurement instruments coupled to the detector analyzed the exhaust sample of the vehicle to determine the level of carbon monoxide (CO). Prior research concerning the technical capability of the RSD had validated the accuracy of the readings for CO and CO_2 as being within + or – 5 percent of readings taken by more traditional methods. As the vehicle passed the detector, a camera took an image of the license plate of the vehicle. As the vehicle continued along the off-ramp, it passed a VMS. A computer controlling the sign received the results of the exhaust analysis of the vehicle. The sign computer displayed a message about the condition of the vehicle that depended on the classification of the emissions analysis of the vehicle. The test classified vehicle emissions as being either GOOD (<1.3 percent CO), FAIR (1.31 to 4.5 percent CO), or POOR (>4.5 percent CO).

All three operational tests have been completed and this review is based on interim and final documents submitted by the test personnel and evaluators.

FINDINGS

The following sections present the findings of this report. The findings present the comparison of the similarities and differences of these three tests and an interpretation of the results. The report organizes the findings into five categories:

- **Impacts**—whether the results of the tests caused changes in the behavior of test participants
- **User Response**—how test participants reacted
- **Technical Lessons Learned**—conclusions about the ease of use, applicability, transferability, and safety of the tested technologies
- **Institutional Challenges and Resolutions** —conclusions about the relationships among the test partners, institutional barriers, and legal issues
- **Cost to Implement**—how the costs may affect the potential development and deployment of the technologies

The document concludes with a Summary of the findings and a Bibliography.

From an operational standpoint, the TDM/ED test and the R-TED test were reasonably similar while the LIDAR test was substantially different. The TDM/ED and R-TED tests used similar technologies to analyze the exhaust of individual vehicles while LIDAR used a prototype system of innovative technology to measure the aggregate pollution effect of the entire traffic stream. This difference has made it difficult in some cases to draw direct comparisons across all three tests. Therefore, in some cases we have discussed the LIDAR test separately from the other two tests.

IMPACTS

Both TDM/ED and R-TED analyzed the exhaust of individual vehicles. R-TED provided immediate feedback to the driver via the associated VMS. The TDM/ED test relied on a mailed survey or notification to advise drivers of the condition of their vehicles. The R-TED method of immediate feedback had a greater impact on drivers than did the TDM/ED method and was more likely to promote the desired effects. LIDAR test personnel did not make their findings available to the general public.

The use made of the information and results of the tests varied widely. The TDM/ED test occurred in Ada County, Idaho. At the time, the EPA had designated Ada County as a non-attainment area for CO. As a non-attainment area, the county had already set up a vehicle emissions testing program. Ada County planning officials explored the use of the TDM/ED system as an additional vehicle emissions control measure and used the test results in several ways. They used the information for transportation planning to reduce CO emissions. They also used the information in considering future enhancements to the County's emissions testing program. Specifically, they considered several options, including:

- Excluding vehicles reliably identified by the test equipment as "clean" (the test results did not define "clean" or "high emitting.") from the testing program, thereby reducing costs to both motorists and the testing program
- Investigating the possibility of requiring vehicle registered outside of the County and reliably identified by the test equipment as "high emitting" to submit to emissions testing
- Expanding the boundaries included in the emissions testing program

Available information does not indicate whether planning officials pursued any of these options. Test evaluators, however, considered that there was evidence that RSD screening, using the average of multiple passes, could identify those vehicles having a high probability of passing an idle emissions test.

The R-TED test collected information similar to the TDM/ED test. In the R-TED test, however, the VMS immediately displayed the condition of the vehicle to the driver. Test personnel evaluated the hypothesis that knowing the condition of their vehicle would prompt drivers of vehicles in poor condition to tune up or repair their vehicle. Denver officials could consider using the R-TED information in a similar manner to the use of the TDM/ED information (i.e., exclude "clean" vehicles from central emission testing and immediately pursue "dirty" vehicles). In Denver, this would require obtaining access to the central emissions testing database to cross-reference the identified vehicles with the test results.

The telephone survey conducted as part of the R-TED test showed that the results displayed on the VMS positively impacted drivers' awareness and knowledge of their car's condition and air quality in general. The sign was not, however, as effective as the test personnel had hoped in reaching the most desired target population (drivers of vehicles with "poor" quality exhaust analyses).

The results from the LIDAR test have a high potential for use in pollution source and dispersion modeling. The LIDAR results could help prove or disprove the basis of assumptions of currently used mathematical models. In addition, if the LIDAR system were equipped with a real-time display capability, the system could dynamically assess

the effects of traffic management measures in a local area.
One aspect of the test attempted to make this assessment but test personnel were unable to gather sufficient information to do so.

The three tests had varying impacts on motorists. Operation of the R-TED equipment did not have a significant impact on motorists since the equipment was located off the roadway and operated unattended. Similarly the LIDAR equipment was set up off the roadway and it is probable that motorists were not even aware that the equipment was operating.
In contrast, operation of the TDM/ED equipment required traffic control and lane restrictions. To obtain its readings, the equipment transmitted an infrared beam across the traffic lane(s). If the equipment spanned two lanes, the equipment could produce invalid readings by sampling the exhaust plumes of more than one vehicle. To avoid this situation, test personnel chose test sites on low volume two-lane roadways or funneled multiple lanes into a single lane. These restrictions caused some congestion and reduction in speed. Test personnel measured speed reductions of from 9 to 38 percent through the test sites. On the only Interstate site, the physical test set up caused enough congestion that test personnel discontinued the test at that site after only one half-hour. In a telephone survey, however, participating drivers did not consider the roadside test equipment to be a hazard. In future tests or in a full deployment, the TDM/ED equipment would have to be restricted to single-lane or low volume two-lane roadways to ensure a high percentage of valid readings. The TDM/ED operation also posed some risk for the test personnel since they had to occasionally cross traffic lanes to service the equipment.

Because of its unobtrusive and unattended operation, the R-TED equipment had less impact on drivers and less risk to test personnel than the TDM/ED equipment.

USER RESPONSE

Driver perceptions about the two individual vehicle emissions tests were favorable. Both tests used a telephone survey of a representative sample of the tested population to gage driver reactions. The survey of TDM/ED participants showed that 72 percent preferred the RSD method of testing emissions, than taking their vehicles to a center for a formal idle emissions test and only 11 percent felt the RSD method was inconvenient. Among these participants, 82 percent thought that the RSD method would encourage more support for emissions testing. In a telephone survey conducted as part of the R-TED test, 59 percent thought the system would result in people repairing their cars and 76 percent thought the VMS was informative. In an in-depth case study conducted as part of the R-TED test, 70 percent of the respondents felt that the information displayed on the sign would stimulate action by vehicle owners. These opinions indicate that people generally would favor testing by these “in-field” methods over going to a testing facility.

Results from these two tests suggest that driver’s intentions and actions are also favorable but these results are more suspect. In the TDM/ED test, test personnel selected 300 participants to test the benefits of offering incentives to improve their car’s emissions analysis. One-hundred of these received a coupon for a free emissions inspection. One-hundred received a coupon for a $20 discount on a tune-up. One-hundred acted as a control group and received a letter notifying them of a possible emissions problem and explaining the benefits of repairing and adjusting their vehicle. Of the group receiving the coupon for an inspection, only eight percent redeemed it. Of the group receiving the discount coupon, none redeemed it. Test personnel telephoned the drivers in the control group. In this group, 33 percent indicated they repaired their vehicles. The results from the two groups offered coupon incentives, however, cast doubt on the results of this telephone survey. If so few of those offered coupon incentives took advantage of them, it does not seem believable that 33 percent of those without incentives would have repaired their vehicles. It is more likely that the telephone respondents enhanced their answers when questioned.

The results from a telephone survey conducted as part of the R-TED test support these doubts. Only eight percent of the R-TED telephone respondents said they intended to have their car checked or maintained. Furthermore, only 1.6 percent claimed they actually acted to repair their vehicle. These claims are more believable but should still be considered carefully.

Nonetheless, if we take the figures from the R-TED survey at face value, the 1.6 percent that acted to improve the performance of their vehicle extrapolates to 4,400 vehicles repaired because of viewing the sign. If each sign installation could generate this level of response, the results would help achieve the general goal of improving air quality.

The LIDAR test did not directly affect drivers, as mentioned above.

TECHNICAL LESSONS LEARNED

The technology used in the TDM/ED and the R-TED tests clearly functioned well and accomplished the intended purposes of those tests. The LIDAR technology was not able to accomplish all of the purposes of its test.

The infrared sensing and the LPR technologies used in the TDM/ED and the R-TED tests functioned well. The TDM/ED equipment took over 45,000 observations. Test personnel analyzed the CO emissions of 31,637 Idaho vehicles with readable license plates. Of these readings, 88 percent of the CO readings in one phase and 92.5 percent in another phase were valid. The RSD software determined the validity of the reading using a confidence factor calculation.

The R-TED system operated unattended, 24 hours per day for nine and one half months and took over three million observations. The R-TED's system uptime (time in operation) percentages varied from 68 to 95 per month. The largest periods of downtime occurred because a contractor working on a nearby construction project severed the power cables leading to the R-TED equipment. Eliminating the downtime due to the construction yields an average of 90 percent uptime per month. During the test, technicians periodically checked the accuracy of the R-TED readings. The readings proved accurate throughout the test requiring only minor recalibrations. Overall, the two infrared sensing technologies prove to be reliable and accurate.

Both of these systems also used LPR technologies that functioned adequately enough for the test purposes. In both systems, rain and other inclement weather conditions (fog, snow, etc.) led to problems in accurately reading license plates. In the first month of operation, the R-TED equipment had almost 30 percent downtime due to inclement weather. In other months, weather did not significantly affect the results. R-TED test personnel did not cite specific figures about LPR accuracy but did not mention any problems. TDM/ED test personnel had to assist the LPR system in recognizing special license plate characters on the Idaho plates. The LPR system, however, was able to successfully read 76 percent of the more than 45,000 observations with minimal staff assistance.

The TDM/ED equipment could only operate reliably on a single lane of traffic. This restriction led evaluators to limit the recommended use of this equipment to low-volume two-lane roadways, three-lane roadways where the center lane is a left-turning lane, and freeway ramps. The equipment could also be used on separated highways with two or more travel lanes in each direction where traffic can be channeled into one lane. During the field test, safety at one interstate highway site became an issue when traffic congestion due to channeling traffic into one lane became excessive. Authorities stopped the test at this site after only one half-hour and removed the equipment and traffic restrictions. In any further application of this technology, test personnel will need to consider carefully the problem of channeling traffic to avoid excessive congestion.

The TDM/ED test was slightly more sophisticated than the R-TED test. In addition to collecting license plate and emissions information, the TDM/ED equipment used a radar device to determine the acceleration of the vehicles at the moment of testing. Acceleration has a marked effect on vehicle emissions. An accelerating vehicle produces far more harmful pollutants than does a vehicle cruising at a steady speed or one decelerating. In fact, a "clean" vehicle in acceleration can produce more harmful emissions than a "dirty" vehicle in its cleanest mode of operation. The TDM/ED test personnel, therefore, considered it important to know the acceleration state of the tested vehicle.

The R-TED test did not measure acceleration. The location of the test site, however, partially compensated for the lack of acceleration information. The R-TED test site was on a curving, uphill ramp. This location, therefore, made it likely that vehicles would always be accelerating at the moment of testing. In future tests, however, this assumption may not be valid. Therefore, in emissions tests under normal driving conditions, test personnel should gather acceleration information since this information can significantly affect the results.

The evaluators of the TDM/ED technology did note several issues that must be considered in planning and using the system. The remote sensing devices were unable to distinguish between cars running poorly (emitting high levels of pollution) and cars that had cold engines (i.e., had only recently been started). Test personnel overcame this problem by locating the testing sites where almost all motorists would have warmed up their engines before reaching the testing site. Evaluators could not develop a strong relationship between a single RSD reading and the idle emissions test result for that vehicle. They were able, however, to improve the confidence of the relationship when the same vehicle passed through the RSD multiple times and the test personnel averaged the readings. The R-TED test tends to confirm this problem by citing examples of drivers who passed through the RSD multiple times and received different readings. The TDM/ED test personnel believe that reliable "cut points" can be developed given a large number of emissions readings. These "cut points" could be used to reliably identify "clean" operating vehicles using multiple readings. These "clean" operating vehicles would have a high probability of passing idle emissions tests. Authorities could use the results of the test analysis to exclude these "clean" operating vehicles from the idle test, thereby saving money and time at no sacrifice of air quality.

Both technologies can be easily transferred and used in other environments.

The LIDAR equipment functioned correctly but its usefulness and practicality is more problematical than the two infrared technologies.

LIDAR test personnel found that proper set up of the equipment was difficult but critical to obtaining accurate results. The equipment must have an unobstructed line-of-sight to the sampling area. To obtain an unobstructed line-of-sight, test personnel had to elevate both the LIDAR equipment and the independent air quality monitoring devices. The monitoring devices had to be elevated because test personnel found it important to aim the laser beam of the LIDAR equipment to within one meter of the intake openings of the devices. The independent monitoring devices were necessary to provide confirmation of the information observed by the LIDAR equipment and to calibrate the LIDAR results. Test personnel also had to be careful during set up to avoid aiming the laser near the ground since the laser is not considered “eye-safe” within the first two kilometers of travel. These factors combined to make set up of the LIDAR tests cumbersome and time-consuming.

LIDAR test personnel also determined that the equipment has several operating restrictions.

Wind conditions can significantly affect the accuracy of results. When measuring particles, a higher speed wind has two effects. One effect is to pick up and carry more larger-sized particles that increase the scattering of the LIDAR beam and reduce the accuracy of readings. A second effect is to increase the mixing of the atmosphere, which dilutes the pollution and, thereby, the accuracy of the measurements. Strong winds also have an affect on CO measurement. A strong wind dilutes CO plumes and weakens the correlation between the LIDAR results and the actual amount of CO pollution. Wind conditions and the elevated platforms for the equipment also introduced a safety problem. During one test session, a 30-mph wind blew the LIDAR device over, breaking a telescope mounting.

Test personnel also found that the equipment was subject to temperature restrictions. During a test session when the temperature dropped below freezing, the LIDAR equipment and the monitoring devices stopped functioning. Test personnel had to shelter and warm the equipment to continue the test.

Another operating restriction is the size of the pollution particles. The LIDAR equipment is most sensitive to particles that are approximately the same diameter as the wave-length of the laser beam. The size of airborne pollution is most often a range, with two concentrations of sizes. Test personnel found that the particle size to which the test laser was most sensitive to was in the trough between particle size concentrations. This observation means that the LIDAR equipment measured particle sizes the may vary considerably and still not be representative of the total volume of pollution. To obtain more accurate measurement of particle concentrations, test personnel recommended using a laser that would be sensitive to particle sizes in the peak area of the size concentration. Using a laser of this wave-length, however, could cause additional laser safety problems.

The LIDAR test determined that operating the laser equipment required two trained technicians and a laser safety officer. Test personnel considered the equipment highly portable and felt that it had good reliability. The test also observed that a large number of readings were necessary to obtain an accurate correlation of the readings. Even after the test equipment was set up and operating, test personnel still considered it necessary to operate the independent monitoring devices to continue to calibrate and validate the LIDAR readings.

Test personnel lamented the lack of real-time display of the data. Test personnel considered having this capability as highly desirable. The test discussion did suggest how to obtain this capability and indicated that one of the partners was working on this issue. Since all data had to be recorded, stored, converted to a common file format, and then integrated for display, the display and analysis of the data required a high skill level. This process also produced a significant delay between the actual test and the time results were available for analysis.

LIDAR evaluators concluded that the system could provide qualitative indications of CO levels under certain, restricted conditions. The system cannot, however, reliably provide quantitative indications of particle mass concentrations. The system can provide important and useful two-and three-dimensional scans of an area with good temporal resolution. These scans can be used to show the origin and relative strength of pollution concentrations. Evaluators believe that the system has the potential to aid in the development and validations of pollution source and dispersion models.

INSTITUTIONAL CHALLENGES AND RESOLUTIONS

The three subject tests did not encounter any serious institutional issues. The partnering arrangements worked well and evaluators did not feel the need to comment on the arrangements. The TDM/ED test was a partnership consisting of all public sector participants led by the metropolitan planning organization of Ada County. The R-TED test was a combined public-private sector partnership in which the public sector partners supplied the technology used. The LIDAR test was also a combined public-private partnership where the private partners supplied the technology. Evaluators in the LIDAR test considered it very advantageous to cooperate with the EPA when selecting site for the tests.

The LIDAR and R-TED tests did not encounter any significant institutional barriers to completing the projects. In the TDM/ED test, the partners addressed several institutional barriers before beginning the test. The partners already had a history of cooperation on other projects. They felt it important to establish and maintain a good working relationship between the local and state transportation agencies to select and set up the testing sites. The partners felt it particularly important to promote a good relationship between the state transportation agency and the local air quality board. To do this they included both agencies in the partnership from the inception of the project. Test partners wrestled with the problem of how to address the "high polluters" registered outside of the air quality board's jurisdiction. There were two reasonable solutions to this problem. The air quality board could expand its jurisdiction to include more of the "high polluter" areas. Alternatively, the board could obtain authority to demand that the high polluting vehicles not registered in the board's jurisdiction be included in the idle emissions testing program. The air quality board found that both solutions would require legislative action. Using the results of the TDM/ED test as support, the board is now exploring in the state legislature the possibility of expanding the boundaries of its jurisdiction.

One potential legal issue surfaced in the two RSD technology tests. Test partners in the TDM/ED test were concerned about the legal ramifications of taking an image of vehicle license plates and using the image to obtain ownership and idle emissions test information about the vehicle. In preparation for the test, the partners obtained a legal opinion from the counsel for the state transportation agency and from the state attorney general. Both counsels said that such a use of the image would not violate privacy laws. The results of the participant surveys conducted in both the TDM/ED and the R-TED tests confirmed this opinion. In both surveys, most participants did not consider taking a license plate image and using it to obtain registration information an invasion of privacy. Specifically, in the R-TED survey, less than one percent considered the system an invasion of privacy.

In both the RSD tests, the partners conducted public awareness campaigns to promote knowledge and understanding of the tests. They publicized the test locations in advance and explained the purpose of the tests. Both tests made extensive use of the print, radio, and television media to conduct their campaigns. The R-TED partners developed and distributed an informational brochure and established a telephone "hotline" that interested people could call. In the follow up participant surveys, the R-TED evaluators found that the news media were the most effective in increasing the awareness of the public. They found that the brochure and "hotline" were not effective. Using the news media seems to be the most effective means to raise public awareness.

COST TO IMPLEMENT

Only the TDM/ED test discussed costs for the test. A cost/benefit analysis was not part of either the R-TED test or the LIDAR test because test partners considered the equipment in both tests a prototype design rather than a potential commercial product.

The TDM/ED test evaluated the actual costs of the test as well as the potential savings the technology could bring. Evaluators calculated that the phase of the test that monitored emissions of all vehicles had a total cost of $111,667 and obtained 15,775 valid emission readings. This led to a unit cost of $7.08 per reading. In contrast, an idle emissions test costs the owner between $12 and $20 per test. Extrapolating these results to a larger scale, the evaluators calculated the potential savings. They envisioned a hybrid emissions program using both RSD technology and idle emissions tests. In this program, the RSD technology would identify a portion of the total vehicle fleet as being "clean" operating. These vehicles would not be tested regularly. The technology would also identify "high emitting" vehicles. These vehicles would be called in for idle emissions tests as soon as identified. The rest of the vehicle fleet would be tested in the regular cycle of testing. Such a program could save vehicle owners between $0.28 and $2.19 annually per registered vehicle, depending on what percentage of vehicles the RSD equipment observed a sufficient number of times (three or more). These costs include the cost of operating and maintaining the RSD equipment.

SUMMARY

The two RSD technology tests show a strong potential for practical application. The technology cannot substitute for a federally mandated idle emissions testing program in an area that has been classed as a non-attainment area. Areas attempting to avoid an EPA designation of non-attainment can, however, use the technology to help identify and track high emitting vehicles. Such areas could implement this type of less-intrusive testing to encourage owners to repair and maintain their high polluting vehicles.

The R-TED technology is relatively simple to set up and operate. Since the system operates unattended, the system would have relatively low operating costs. The participant surveys show that the system can produce the desired responses in the driving public, e.g. encouraging repairs and tune-ups of the vehicle fleet. For metropolitan areas prone to air quality problems, establishing such a system could be considered as part of a solution to the air quality problem. Establishing a network of similar systems that would test and notify a large portion of the driving public could be a cost-effective manner of promoting awareness of vehicle emissions and encouraging desired behavior.

The TDM/ED evaluators felt the greatest benefit of the system would be the process of "excluding" clean operating vehicles from the regular emissions testing program. In preparatory research, evaluators learned that as much as 90 percent of the vehicle fleet operates cleanly. Yet idle emissions test programs test 100 percent of the vehicles. Excluding from testing a portion of the 90 percent of the fleet that operate cleanly can produce a substantial reduction of the cost of a testing program while still maintaining or reducing pollution. The hybrid program described in the Cost to Implement section above, is an example to how such a program could be implemented.

The LIDAR test demonstrated both the potential and the problems of the technology. The prototype operated accurately under only very restrictive conditions of location and pollution type. Although the system was restricted by not having a real-time display capability, this problem could be overcome. Even if the prototype were perfected, evaluators felt there would still be a need for independent air quality monitoring devices to verify or calibrate the LIDAR equipment measurements. In short the system is cumbersome to operate and suffers from significant restrictions during operations. The current version of the system is not practical for traffic pollution monitoring.

The LIDAR system does have potential in a more theoretical area. The system's two and three dimensional representations of a pollutant plume can help the development and validation of source and dispersion models. The effective temporal resolution of the LIDAR system and the graphical representation of the plume could aid investigators as they construct and prove mathematical models of how pollutants move through the atmosphere.

This group of tests demonstrated potential systems that can address the concerns of citizens and government officials about air quality. The RSD tests show some promise in helping officials manage the vehicle emissions problem in a cost-effective manner. The LIDAR test holds out the potential to speed research on the movement of air pollution.

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Publication No. FHWA-JPO-99-039
HVH-1/9-98