Clearing the Air

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For residents of Denver, Colorado, poor air quality is a pressing problem, largely caused by vehicle exhaust. To see if ITS technologies could be applied to help improve air quality, the Colorado Department of Transportation initiated the Smart Sign project, also known as IVHS for Voluntary Emissions Reduction. The ITS operational test combined a remote sensing device that analyzed vehicle emissions and a changeable message sign, which displayed “good,” “fair,” or “poor” readings to drivers in real time. The project offered the potential to dramatically increase drivers’ awareness of their vehicle emissions, to encourage the minority of motorists who drive grossly polluting vehicles to accept responsibility for their dirty cars, and to alert owners of normally low-emitting vehicles if an emissions system failure had occurred.

Getting started
The Smart Sign project grew out of a research program in the late 1980s at the University of Denver to develop remote sensing technologies for vehicle exhaust. In 1993, the university and the Colorado Department of Transportation collaborated and won more than $300,000 in federal ITS funding for the project. The University of Denver managed the technical aspects of the project and Colorado State University’s National Center for Vehicle Emissions and Safety conducted the independent evaluation. Conoco Oil funded the design of the car graphic on the sign and distributed brochures at its gas stations and convenience stores.

How it worked
The changeable message sign (Skyline Products, Colorado Springs, Colorado) and the remote sensing device (Remote Sensing Technologies, Tucson, Arizona) were combined to create a remote sensing information system (RSIS). The system was tested at the busy interchange at Interstate 25 and Speer Boulevard in Denver between May 1996 and August 1997.

Emissions analysis. The emissions analysis began when a car passed through an infrared beam that the analyzer shot across the roadway at tailpipe level. The remote sensing device operated under a manhole with a periscope — two flat mirrors that brought the beam above ground. When a car broke the beam, the sensor read the tailpipe emissions, the analyzer measured the amount of carbon monoxide using an analytical chemistry technique called absorption spectroscopy, and the sign flashed the results. If the carbon monoxide level was good — 86 percent of cars got “good” ratings — a smiley face appeared on the sign along with the message “Saving you money!” Cars with “fair” ratings got an “uh-oh” face, and “poor” ratings earned a frown — both of which prompted the message “Costing you money!” The entire process took about 2 seconds, depending on vehicle speed.

We used a license-plate recognition (LPR) system (Percepts, Knoxville, Tennessee) to identify potential survey participants for project evaluation. The setback for the LPR was 75 feet, the field of view about six feet wide, and the ramp 24 feet wide. Under these conditions, the LPR successfully recorded about 1000 plates per day.

An optical car-detection beam (Banner, Minneapolis, Minnesota)
triggered the LPR strobe lamp and software. Because we thought rearward reflection of the strobe lamp might be distracting at night, we operated the LPR only during daylight hours.

A second, identical, optical car-detection beam was placed farther up the ramp, at the point where each vehicle pointed directly at the sign. A microcomputer (Blue Earth, Mankato, Minnesota) stored the readings from the lower computer and, as each car passed through the second beam, read them back to the sign in the order received.

The computers for both the LPR and the remote sensor were housed in an aluminum traffic signal control box. They were programmed to operate the system, recover from power outages, and automatically answer a modem so the software could be remotely controlled.

The sign was designed to operate at two levels of brightness (daylight and dark), triggered by a solar cell. It operated trouble-free for all 14 months of the test. Red-orange and green LEDs were used for the variable messages. The fixed message was back-lit with conventional fluorescent tubes.

**Evaluation and results**

Our evaluation of the Smart Sign project was two-fold: technical and behavioral.

**Technical evaluation.** The technical component of the evaluation was designed to determine the effectiveness of the technology itself. First we asked, Did the combination of technologies work? The data log from an onboard exhaust analyzer (Owatonna Tool Corporation, Owatonna, Wisconsin) showed no indications that the underground system did not function as intended, except under conditions such as rain and snow — when the sign automatically shut down — accidents, equipment failure, and unforeseen events. Overall, the system operated about 91 percent of the time in the first 12 months of the test. One-third of the down time was caused by contractors digging through the underground cables.

Secondly we asked, Were motorists' emissions measured and reported accurately? Data from the onboard analyzer suggested no malfunctions in the sign's ability to report the correct category of the vehicle's carbon monoxide emissions, allowing fluctuations of plus or minus 3 percent.

Lastly we wanted to know, Was the correct information displayed to the appropriate motorist? According to feedback from motorists, we believe it was: Only 1 percent of the respondents from our behavioral survey (outlined below) felt they weren't getting the right information.

**The system software was written to invalidate a vehicle's signal if another vehicle followed it too closely and to display only the reading for the rear vehicle. If the two vehicle-detector beams were blocked for too long or if the gap between detections was too short, the sign automatically displayed no reading, and all vehicle detection systems were reset at the next eighth-second gap in traffic. We estimate that these problems caused incorrect readings for less than 0.7 percent of the vehicles and no readings for about 1 percent.**

**Behavioral evaluation.** To assess the effects of the Smart Sign project on motorists' behavior, we conducted telephone interviews with 474 people who drove by the RSIS. The sample analysis was weighted to represent the actual population passing the sign. The behavioral assessment was designed to answer five questions:

- **Did the system influence drivers' awareness of emissions levels?**
- **Did it improve knowledge of the relationship between emissions, maintenance/repair and fuel economy?**
- **Did the emissions information influence intentions, such as convincing drivers to repair vehicles?**
- **Did motorists actually do anything in response to the sign?**

Approximately two-thirds of the weighted population thought the sign was informative. In general, respondents who received ratings of "good" recalled their readings better and drove by the check point more often than those we knew had received either "poor" or "fair" ratings. We did not reach our target population, the "poor" stratum, as often as we would have liked.

Most respondents told us they understood the relationship between tailpipe emissions, maintenance, and fuel economy. Ninety-nine percent believed that maintenance is important, and most maintained their cars at regular intervals. Ninety-five percent agreed that a well-maintained car saves money.

Eight percent of those polled planned to do something in response to the sign. Respondents in the "poor" stratum (31 percent) were almost twice as likely to respond to the system as those in the "fair" stratum (16 percent) and five times as likely as those in the "good" stratum (6 percent). This is a good indication that the stratum most in need of the information from the sign is the one most likely to respond.

Approximately two percent of the weighted population (1.6 percent of the overall fleet) reported taking some action, which indicates the system is motivating motorists to improve the condition of their cars. The sign has delivered 3 million readings to about 232,000 unique vehicles, so extrapolating the results of our sample allows us to predict more than 4000 voluntary repairs.

We interviewed a subsample of the telephone respondents (20 people) using in-depth case-study techniques to better understand the reasoning behind the responses to the questionnaire. Seventy percent of the case-study participants felt the sign could stimulate action among the driving public. More than half of those in the "poor" category found the sign interesting and were in favor of it. Most of those with "good" emissions readings said they would fix their cars if they received a "fair" or "poor" reading. They also felt that the sign would encourage people to take action.
Suggestions for improvement

Throughout the evaluation phase of the Smart Sign project, participating motorists made recommendations on how to improve the program, including the following:

- Place the sign in a relatively uncongested area so drivers can concentrate on it and be sure that the reading is connected to the right car.
- Place an informational sign before the sign showing test results to explain the test and prepare people to read the results.
- Personalize the messages.
- Clarify what "good," "fair," and "poor" mean and what is measured, perhaps by introducing a scale to show the relativity of the reading.
- Educate drivers about the who, why, and what of the program.
- Use radio to provide additional information.
- Develop a grants program for low-income drivers to repair their vehicles.
- Provide coupons from the private sector for vehicle repair.
- Connect incentives to an existing program that provides access to diagnostic facilities between mandatory test periods.
- Use the word "emissions" on the sign, instead of "health," because "Your car's health" is too vague.

Conclusion

Now that the project has been completed, active discussions are taking place regarding several possible scenarios, including:

- finding additional funding to resume operating the system at its current location
- moving the system (if funds become available)
- mounting the sign on a trailer to make the whole system portable so motorists outside the Denver metropolitan area could use it.

The Colorado Department of Public Health and the Environment is currently evaluating the use of remote sensing in Greeley, Colorado. It believes the technology is appropriate for use as a screening tool. Our project's demonstration of an unstaffed, reasonably accurate emissions testing system opens the possibility of significantly reducing the costs of staffing existing centers. The department will continue to explore that possibility as the state's remote sensing program develops.