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Remote Sensing of Vehicle Emissions, Case Study: Thessaloniki, Greece (Presentation)

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REMOTE SENSING OF VEHICLE EMISSIONS

CASE STUDY: THESSALONIKI GREECE

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ABSTRACT

A remote sensing system (called FEAT: Fuel Efficiency Automobile Test) was used to make over 10.000 valid motor vehicle carbon monoxide (CO) and hydrocarbon (HC) emission measurements in the Thessaloniki area (Greece).

FEAT is made up of three basic units: the IR source, an IR photo voltaic light detector and a computer. The IR source sends a horizontal beam of radiation across a single traffic lane and the beam is picked up by the detector on the opposite side and split into four wavelength channels : CO, CO_2 ,and HC in the exhaust plume. For every vehicle that passes through the IR beam, the computer freezes a videotaped picture of the rear end of the vehicle showing the license plate number and a read-out of the percentage of CO, CO_2 and HC in the exhaust plume. The results are stored on a digital computer data-base including the date, time and emissions, as well as on S-VHS videotapes.

The results indicated that more than half of the CO was emitted by 15% of the vehicles-the "gross polluters". About half of the HC was emitted by 10% of the vehicles tested. The average CO emissions for the measured fleet was 1.37% CO and the average emission of HC was 0.16% HC.

These results imply that an inspection and maintenance Program incorporating remote sensing has the potential to identify a significant fraction of the on-road CO and HC emissions, while producing very large gains in emissions reduction.

INTRODUCTION

Mobile sources are believed to contribute a significant portion to emissions of CO, HC and NOx. These pollutants are very determinant for formation of the photochemical smog in an urban area. [1]

Air pollution control measures taken to mitigate mobile source emissions include inspection and maintenance programs (I+M).

Nonetheless, despite two decades of air pollution control efforts, many people continue to live in areas where the air is unhealthy. In USA for example, vehicle -miles- travelled (VMT) increased on average of 4.4 percent annually during the 1980's while the population increased 2.5 percent. Annually, cars and trucks in the USA now travel 2 trillion miles compared to 1 trillion in 1970.

With initial support from the Colorado Office of Energy Conservation in 1987, the University of Denver developed an Infra-Red (IR) remote sensing system for vehicle carbon monoxide (CO) and hydrocarbons (HC) exhaust emissions (called FEAT for Fuel Efficiency Automobile Test).

THE INSTRUMENT

The remote sensing instrument measures the CO and HC percentage in the exhaust of any vehicle passing through an IR light beam which is transmitted across a single-lane of roadway. (see Figure 1) [1,2]

FEAT can measure the CO and HC emissions in all vehicles, including gasoline and diesel-powered vehicles, as long as the exhaust plume exits the vehicle within a few feet of the ground. Due to the current height of the sensing beam, FEAT will not register emissions from exhausts which exit from the top of vehicles such as for heavy - duty diesel vehicles. The CO and HC emissions from diesel vehicles are in any case, relatively unimportant.

The IR source sends a horizontal beam of radiation across a single traffic lane, approximately 10 inches Placed in front of the detector is an optical filter that transmits the IR light of a wavelength known to be uniquely absorbed by the molecule of interest. The absorption of light by the molecules of interest reduces

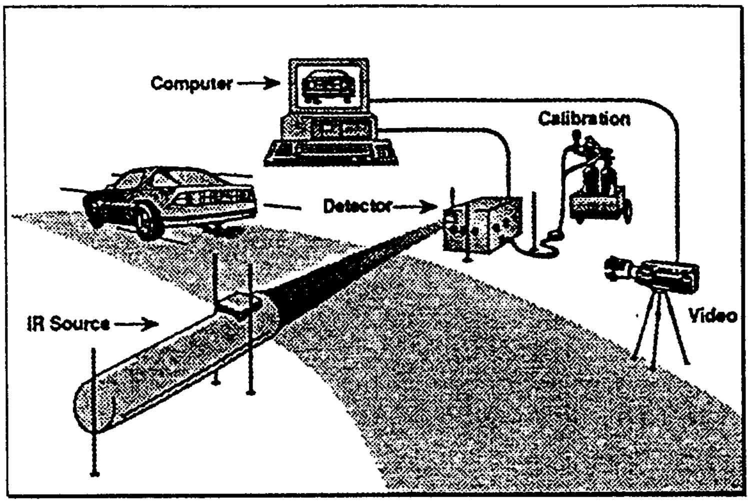

Figure 1 The Remote Sensing System

the signal, causing a reduction in the output voltage.
FEAT measures the exhaust from a car that drives between an IR source and the detector. Each time the IR beam is blocked, this initiates an analysis for vehicle exhaust.
Error checking routines in the FEAT computer eliminate invalid data caused by oversized vehicles, pedestrians or other non-exhaust obstacles.
The calibration gases (mixtures of CO, propane and CO_2) are used as a daily quality assurance check on system.
The system works by sampling in front of and behind the vehicle and registering the difference - hence, there is no impact on the measurements of the ambient air quality conditions. Also, there is no impact on measurements from the pollution plume left by a previous vehicle.
For every vehicle that passes through the IR beam, the computer freezes a videotaped picture of the rear end of the vehicle showing the license plate number and a read-out of the percentage of CO, CO_2, and HC in the exhaust plume.
The results are stored on a digital computer data-base including the date, time and emissions, as well as on S-VHS videotapes. The computer writes the date, time and the calculated exhaust CO, HC and CO_2 percentage concentrations at the bottom of the image.
The software that runs the FEAT system has been written with the idea that it is better to declare that a given vehicle's emissions were not measured correctly than to let erroneous data into the database. The software contains many checks for detecting potential errors. When errors are detected, the measurement is rejected and an invalid data flag is set in the database.
The CO and HC percentage can be determined by remote sensing, independent of wind, temperature and turbulence in 0.9 seconds per passing car. FEAT has been shown to give correct reading for CO and HC by means of double-blind studies of vehicles both on the road and on dynamometers.
FEAT is effective across traffic lanes of up to 40 feet in width. However, it can only operate across a single - lane of traffic if one wishes to identify positively and video-record each vehicle with its exhaust. FEAT operates most effectively on dry pavement. Rain, snow and very wet pavement cause scattering of the IR beam. These interferences cause the frequency of invalid readings to increase, ultimately to the point that all data are rejected as being contaminated by too much "noise".
Another cause of rejection is unreadable plates which were sometimes the result of the vehicle position in the video field at the instant of instrument triggering. This effect randomly removes vehicles and so will not affect the statistics of the remaining data. [1,3]

DATA TRANSMISSION

Data produced at remote sensing station must be transmitted to the point at which immediate use of the data is to be made (like traffic control authorities, vehicle technical control centres etc.) or at which the data are further processed and stored.

There are many circumstances that argue in favor of the use of telemetry systems for transmission of data from remote sensing stations to a central station for display, action or input to the data reduction system.
The most important of these circumstances include real-time need for data to activate emergency action systems and for use in forecasting or simulation modelling operations.
In the form of automated data acquisition system (which is very popular in air pollution monitoring systems), a minicomputer is used at the central station to receive and process data and to otherwise interface with the system.
Some of the operations which can be performed include:
a) linearize and scale raw data.
b) average instantaneous data points.
c) perform edit routines such as checking for"out-of-limits" emissions.
d) flag and print out values above preset limits. [8]

COMPARISON OF REMOTE SENSING AND EXISTING INSPECTION AND MAINTENANCE SYSTEMS

1. The cost is less than 0.5 $ per car with R.S. and it is higher than 10 $ per car with I.M.
2. The measurement time is 1000 cars per hour with RS and 10 cars per hour with I.M.
3. The data can be teletransmitted rapidly with RS while, they are treated non-automatically with IM.
4. The accuracy is better than 5% for both systems.
5. There is an unobtrusive on road test with RS while all owners are inconvenienced with IM.
6. The fleet problems are identified quickly with RS while with IM, there are too few tests for quick response.
7. There is no way to cheat the test using RS while, there is advance notice to cheaters with IM. [1,3]

RESULTS AND DISCUSSION

This remote sensing system was used to make over 10.000 motor vehicle CO and HC emission measurements in Thessaloniki area (in Northern Greece), in a single-lane of a roadway.
There was a statistical treatment of the data and the videotapes were read for license plate identification.
The analysis to correlate the emissions to the age, model and make of the vehicle is continued for Thessaloniki data.
The results are presented in the following FIGURES.
The Figure (2) shows the distribution of CO emissions by percent CO category for the 10.000 vehicles measured.
The distribution of the data is that more than half the emissions come from 15% (percent) of the vehicles. These cars are referred as "Gross CO Polluters".
Consequently, the 85% of the vehicles is responsible only for the other half of the emissions.

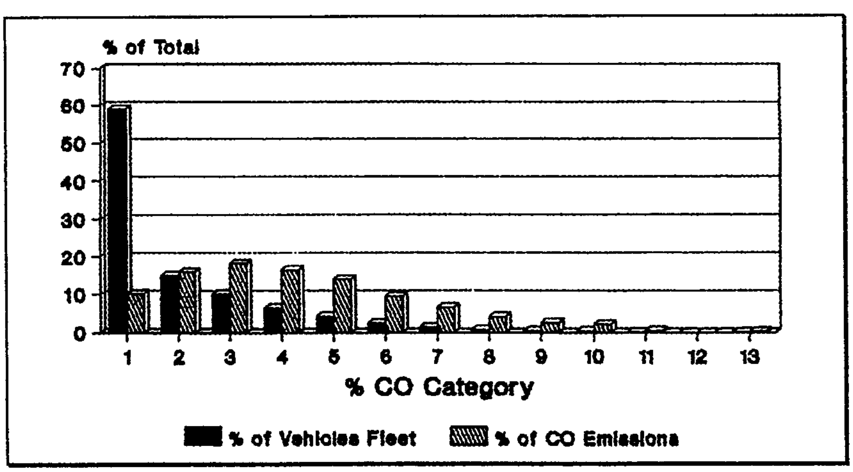

Figure 2 Distribution of CO emissions by percent CO category. Thessaloniki-Greece

The Figure (3) illustrates, in a different way the overall sample fleet. The sample has been subdivided into tenths and the height of each bar represents the overage emissions for that tenth of the sample fleet.
The distribution of the data is that the 70% of the cars are clean with CO emissions less than 1% (limit value: 3%).
Only the 10% of the cars present CO emissions higher than 3% (the mean value of this category is ~ 5%)
The graphs show even more clearly the impact of the gross polluters representing the dirtiest 10 and 20% of vehicles. Clearly, vehicles in the two highest deciles produce by far the largest contribution to CO emissions. Removal or remediation of these vehicles would clearly provide considerable reduction in mobile emissions.

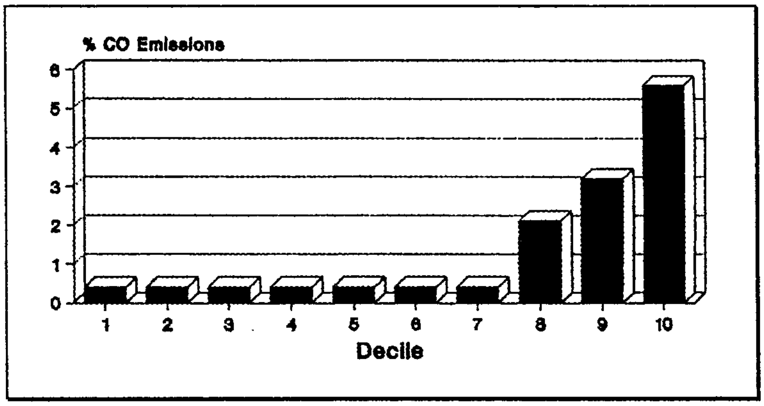

Figure 3 Overall sample fleet CO emissions subdivided into tenths. Thessaloniki Greece

The Figure (4) shows the distribution of HC emissions by percent HC category for the 10.000 vehicles measured.
The distribution of the data is that more than half the emissions come from 10% of the vehicles.
Consequently, the 90% of the vehicles is responsible only for the other half of the emissions.

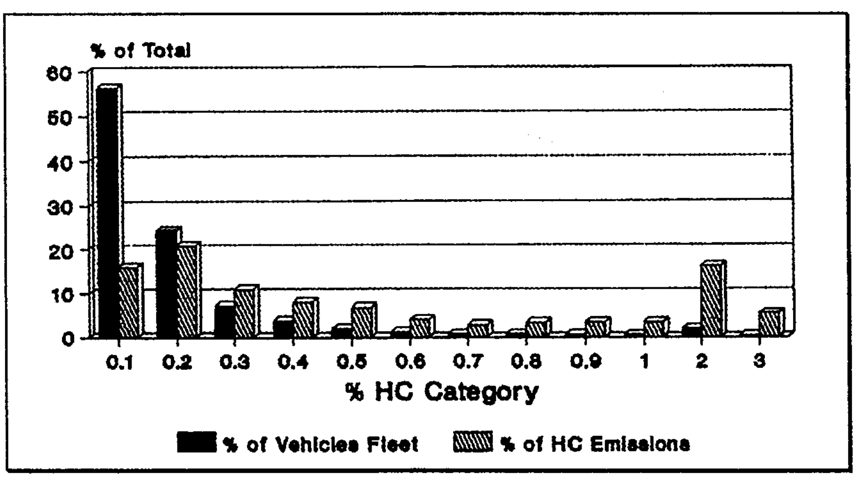

Figure 4 *Distribution of HC emissions by percent HC category. Thessaloniki-Greece*

The Figure (5) illustrates the overall sample fleet subdivided into tenths.
The distribution of the data is that the 70% of the cars are clean with HC emissions less than 0,1% (limit value :0,3%).
Only the 10% of the cars present HC emissions higher than 0,3% (the mean value of this category is ~0,7 %).
The graphs show even more clearly that vehicles in the two highest deciles (gross HC polluters)produce by far the largest contribution to HC emissions.

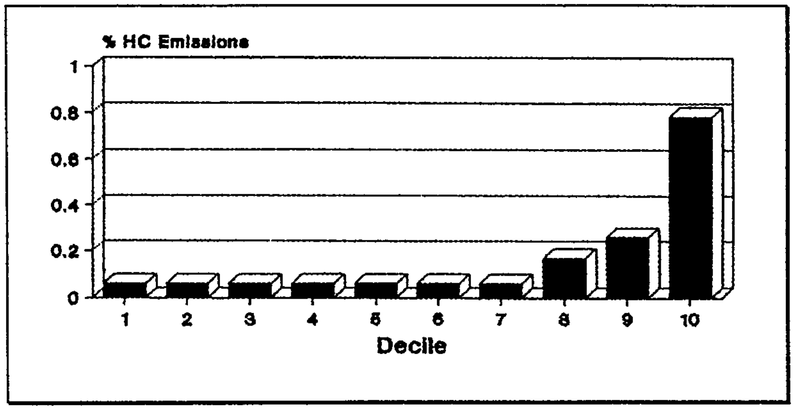

Figure 5 *Overall sample fleet HC emissions subdivided into tenths. Thessaloniki Greece*

The two following Figures show a 56.000 vehicle measurement data set from Los Angeles [4], London [5], Mexico City [6] and Gothenburg (Sweden) [7].

The Figure (6) illustrates a separation of our vehicle measurements for which registration data exists into groups by model year. Each model year is rank ordered by % CO emissions and divided into five equal size parts (quintiles).

The emissions of each quintile is averaged.

From this Figure, it can be seen that the dirtiest quintile of the newest vehicles (1991) has much higher emissions than the cleanest quintile of the oldest vehicles (1964 and older).

It can also be seen that the most rapid deterioration in emissions occurs during the first five to six years of ownership. After that time the rate of increase of emissions slows down considerably.

It is interesting to note that these vehicles with the most rapidly deteriorating emissions are all new technology vehicles with computer controlled fuel delivery systems and three-way catalysts.

All of these vehicles have negligible CO emissions when first purchased.

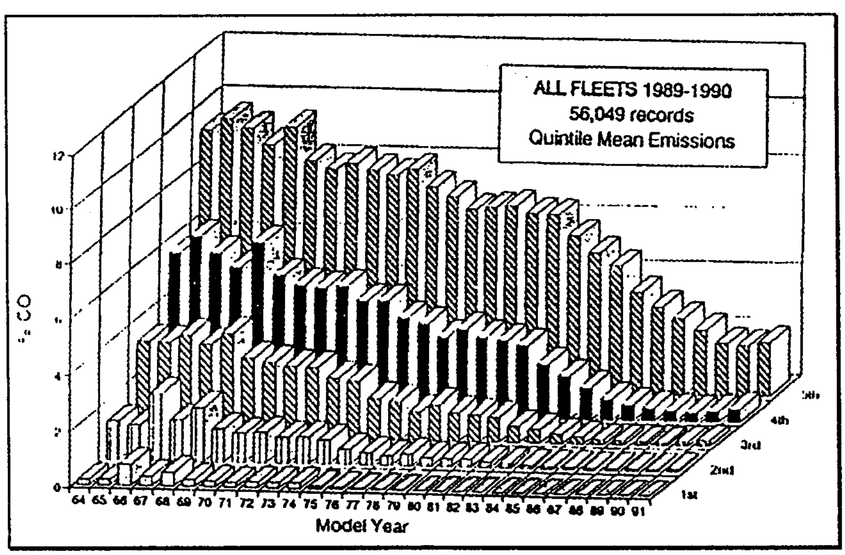

Figure 6 Separation of vehicle measurements for which registration data exists into groups by model year. Each model year is rank ordered by % CO emissions and divided into five equal size parts (quintiles).The emissions of each quintile is averaged.

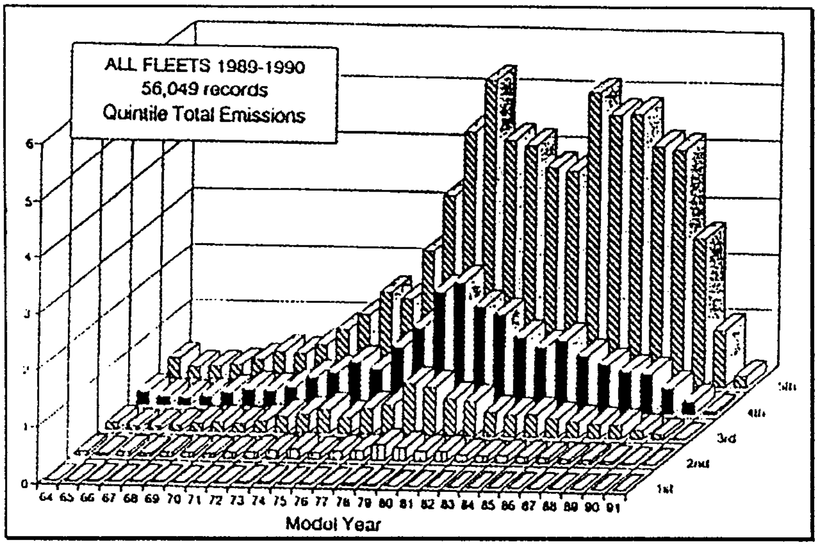

Figure 7 Each quintile of Figure (6) is multiplied by the number of vehicles in that quintile. Each quintile now shows its contribution to total fleet emissions.

On the Figure (7), each quintile of Figure (6) is multiplied by the number of vehicles in that quintile. Each quintile now shows its contribution to total fleet emissions.

The more numerous newer, dirty vehicles dominate the fleet CO output. What it shows is that too much concern about the emissions of older vehicles is not warranted because there are so few of them out on the road. The emissions from the dirtiest quintile of the 1990 vehicles (one year old) is much higher than the dirtiest quintile of the 1964 and older fleet. Again this is due to the greater number of one year old vehicles in the fleet compared to those 17 years and older.

Both these Figures demonstrate that vehicle maintenance is a more important consideration than vehicle age in determining and controlling fleet emissions.

New fleets regardless of make all have nearly identical and very low emissions.

Since the average emissions of all fleets is dominated by a small percentage of dirty vehicles, we believe the differences over time are caused by maintenance factors.

There are two factors affecting maintenance.

The first is the owner's willingness to pay for required maintenance.

The second is the manufacturer's ability to provide a vehicle which either requires little maintenance or can be easily repaired when maintenance is required.

CONCLUSIONS

- The measurement, by the IR remote sensor, of the 10.000 on-road vehicle emissions in Thessaloniki show that only a small percentage of vehicles (10-15%) contribute to more than half of the pollution from CO and HC.
- These vehicles called "Gross Polluters" are not only old technology or old model vehicles.
- The more numerous newer, dirty vehicles dominate the fleet emissions.
- The results from vehicle emissions measurements in different cities in the world (Los Angeles-USA,London-U.K., Mexico City-Mexico, Gothenburg-Sweden and Thessaloniki-Greece) demonstrate that maintenance is a very important factor in controlling car emissions.
- The use of the IR remote sensor permits, for the first time, the application of the telemetry and consequently the rapid data transmission in order to activate emergency action systems or car control systems, without inconveniencing the big fraction of the vehicle owners, while producing very large gains in emissions reduction.

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