quality and other goals for metropolitan areas. The first conclusion is that stationary-source controls as a group were found to be more effective in directly reducing hydrocarbon emissions than mobile-source controls. Certain transportation controls that incorporated user costs were found generally to be more cost-effective than stationary-source controls even though their emission-reduction potential was not so great.

The incorporation of user cost considerations was found to reduce the net cost of emission reductions, and in the application in the Philadelphia region this amounted to $100 million annually. The methodology shown incorporates preliminary and more-detailed screening and a wide range of factors, some of which can be quantified and some of which cannot. It was found that by using this kind of methodology, looking at a number of alternatives, and making trade-offs between stationary and mobile sources, a timetable for the achievement of the ozone standard can be developed based on cost-effectiveness considerations. This gives a more realistic timetable for attainment of the standard.

A second finding is that integration of the results of both stationary and mobile sources is a better way to achieve air-quality goals. Since the Clean Air Act was passed, air-quality specialists have been divided into those who advocate control of stationary sources and those who advocate control of mobile sources. The methodology discussed here forces the two groups to get together to provide inputs on the costs and share with one another the impacts of the program, some of which can be quantified.

A third finding is that user cost considerations of transportation are needed in performing the cost-effectiveness analysis. Last, it is suggested that a cost-effectiveness rather than a cost-benefit framework be used by metropolitan areas in developing their SIPs.

REFERENCE

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Publication of this paper sponsored by Committee on Transportation and Air Quality.

Guidance from Disaggregate Emissions Inventory in Selection of Control Measures

KATHY BAILEY, MICHAEL CLIFFORD, AND PHILLIP SHAPIRO

A three-phase plan for development of an air-quality control program is discussed. The Council of Governments in Washington, D.C., has developed a plan in which phase 1 consists of development of a disaggregate emissions inventory, projection of emission levels for 1981, and sensitivity analyses. In phase 2 the control measures are defined and evaluated. Phase 3 involves seeking commitments by local governments and writing the plan.

The Council of Governments (COG) in Washington, D.C., has developed a three-phase plan for development of an air-quality control program in which phase 1 consists of development of disaggregate emissions inventory, projection of emission levels for 1987, and sensitivity analyses. In phase 2 the control measures are defined and evaluated. Phase 3 involves seeking commitments by local governments and writing the plan.

COG has been designated to do air-quality planning for a relatively large region, which covers three states (Maryland, Virginia, and the District of Columbia, if the District of Columbia is considered a state). Essentially all the work on the state implementation plans (SIPs) for the District and for portions of Maryland and Virginia is done by COG.

The work at COG is similar to the work states in other parts of the country are doing: developing the inventory for both stationary and mobile sources and examining and evaluating control measures. COG works with the states and the local jurisdictions, but the responsibility lies mainly with COG for the development of the plan that will form the basis for SIP revision. COG uses an interdisciplinary approach; several different departments work on the program. The Department of Environmental Programs has been given responsibility for overall coordination and management of the program as well as development of the stationary-source portion of the inventory (phase 1). The Department of Transportation Planning is responsible for development of the mobile-source portion of the inventory. In phase 2 the departments are working together to evaluate control measures; the Department of Community and Economic Resources is providing input to the evaluation of some measures. Also, the COG Computer Center has provided a programmer/analyst who worked on the inventory for almost a year.

COG started this program almost 2 yr ago. It was divided into three main parts. First, the problem had to be better defined. Previous work was inadequate for the level of detail that was needed. It would have been inconsistent to use data generated in earlier efforts to compare with the 1980 data. Phase 1 of the planning effort consisted of defining the problem and developing the detailed inventory that is the focus of this paper. Once the inventory had been developed, it showed emission levels that were too high to satisfy the ozone standard. Next came phase 2, the stage in which control measures were considered. More than 50 control measures were defined and are currently being evaluated. Phase 3 will involve seeking commitments and writing the plan.

Phase 1 also had three parts. First, emissions inventories for both 1980 and 1987 were developed.

Figure 1. Vehicle trips by mode and purpose: 1980 versus 1987.

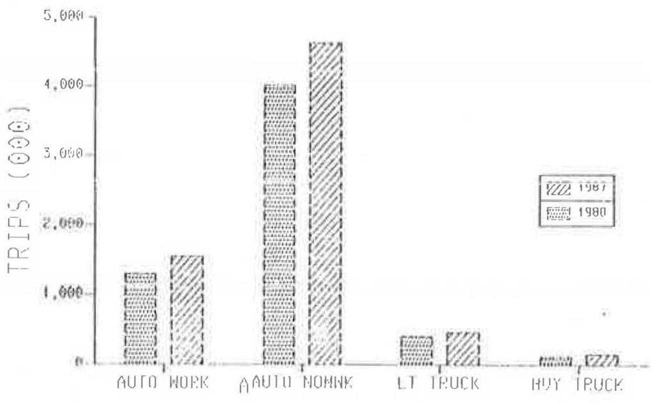


Figure 2. Daily VMT by mode and purpose: 1980 versus 1987.

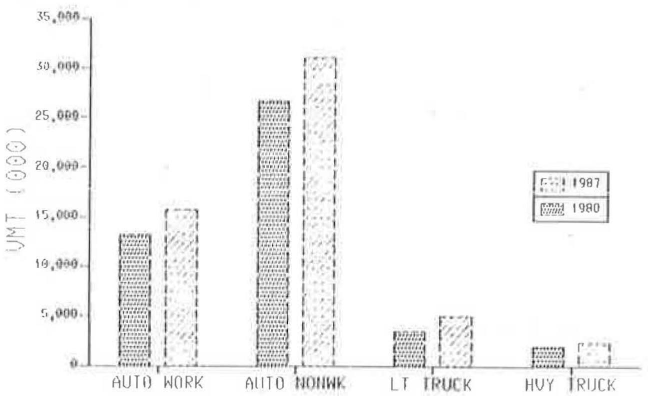


Figure 3. Automobile running emission rates for hydrocarbon and nitrogen oxide by model year.

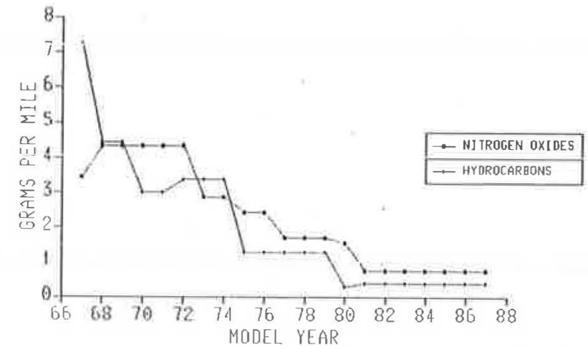


Figure 4. Automobile running emission rates for hydrocarbon and nitrogen oxide by calendar year.

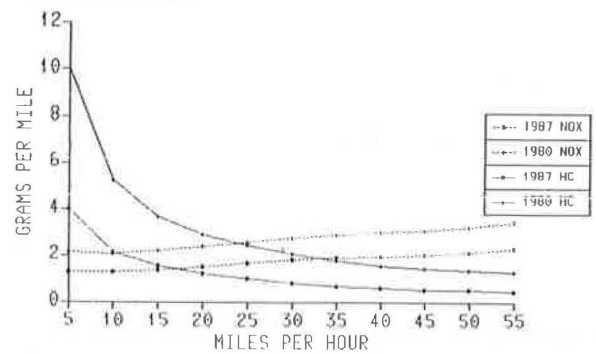
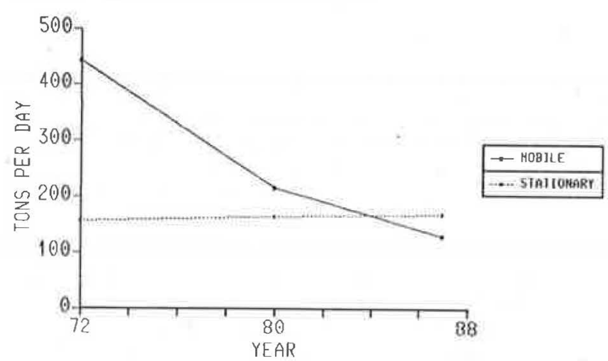


Figure 5. Hydrocarbon emissions by source.



Both the stationary-source and mobile-source portions of each inventory were broken down into several categories. One interesting result of this breakdown was the response received from the public. When, for example, the dry cleaner or the service station owner saw what portion of the total emissions was theirs, they could relate to that, and it turned out to be a good way to get public and industry involvement. The importance of each of the different categories to the overall total emissions became clear. Thus it was possible to obtain from different industry groups data that had not been available before, which in some cases replaced U.S. Environmental Protection Agency (EPA) default values. This helped to make the inventory Washington-specific as well as more detailed.

Another item to note is the point sources. There is virtually no industry in the region. If a limit of 100 tons/yr had been used for point sources, only about three sources in the entire Washington region would have qualified as being over the limit. Because each of the states keeps detailed records of emission rates for point sources to be used when permits are granted, it was decided to reduce the point-source limit to 25 tons/yr.

The second part of defining the problem, after these emissions data had been obtained, was to project what was going to happen by 1987. Were the data without the controls going to be too high? Was the ozone standard going to be met? To determine the answers, the city-specific empirical kinetic modeling approach was used, and it was found that hydro-carbon emissions would have to be reduced from 1980 levels by about 45 percent in order to meet the standard by 1987. That is a tremendous task in a region in which there is little industry to clean up.

The third part of defining the problem involved sensitivity analyses; a series of tests was performed to see what kind of changes would be required in various inputs, such as vehicle miles of travel (VMT) and so forth, before a change in the outputs could be seen. It took much bigger changes than had been expected to produce significant results.

TRAVEL ESTIMATES

The 1980 emissions inventory represents a simulation of existing conditions; the 1987 travel estimate is the base case for SIP development. It includes no controls other than 1987 emission factors; there is an inspection maintenance program in each state.

Figure 6. Hydrocarbon emissions by source: 1980 versus 1987.

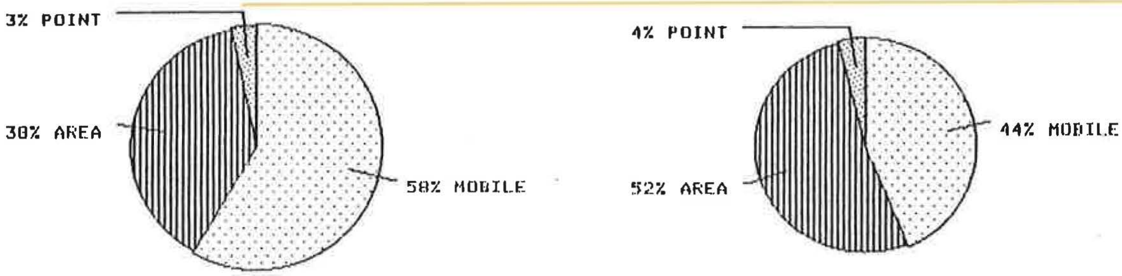
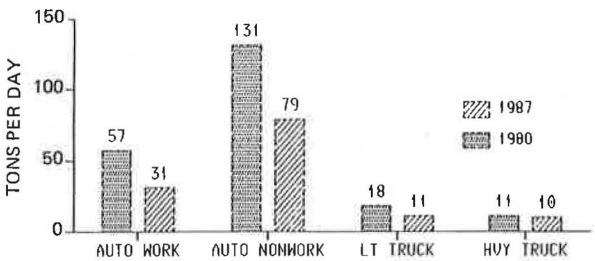


Figure 7. Mobile-source hydrocarbon emissions by mode and purpose.



The travel forecast was prepared in each case by using the traditional four-step modeling process; an additional step, generation of off-network travel, was used for later development of separate running and trip-end emissions. In the next step, travel-related data were used to prepare the average speed requirements, estimates of cold starts, and distributions of daily travel and travel by time of day. Transportation facility assumptions included, for highways, the best guess of what facilities will exist in 1987 made by the local and state operating agencies; for example, in Virginia I-66 and the Dulles toll road and in Maryland I-370 and Great Seneca Parkway. For transit, 1980 Metro rail was used in both the 1980 and 1987 inventories. Although a subway is under construction now and more of it will be in operation in 1987, Metro rail was evaluated separately because it was a control measure in the 1979 SIP.

Considering the results of the traffic simulations, Figure 1 shows that vehicle trips increase about 16 percent between 1980 and 1987, or about 2.2 percent per year. Figure 1 also shows that there are about three times as many automobile nonwork trips as automobile work trips. Figure 2 has been prepared to show VMT. There is roughly a 20 percent increase in VMT between 1980 and 1987, or about 2.5 percent increase per year. There is now twice as much nonwork VMT as work VMT because of longer trip lengths to work.

EMISSION FACTORS

Figure 3 shows how the allowable emission rates for hydrocarbons and nitrogen oxides have changed since motor vehicles were first controlled in 1968: Significant decreases in the factors may be seen. The curve is not a continuing decrease because the data points plotted are not for the legislated rates; rather, they are results of EPA's testing of new cars off the assembly line for each year. To show how the rates have changed, for example, the 1980 hydrocarbon rate is 5 percent of the rate under precontrol conditions, and the 1980 nitrogen oxide rate is about 22 percent of the precontrol rate. The rates taper down to the current model years, when automobiles are as clean as they are ever going to be, and are shown constant into the future.

The effect of new-car controls on a region's average mix of vehicles is shown in Figure 4, where the average vehicle mix in the Washington area is presented. Two sets of parallel lines may be seen, one for hydrocarbon emissions, which decrease with increasing speed, and one for nitrogen oxides, which increase at faster speeds. The influence of the new-car standards is shown because in each case the lower of the two lines represents 1987 emission factors. As older cars are replaced with new, cleaner vehicles, the average emission factor for the vehicle mix decreases. For example, at 40 mph the emission factor for hydrocarbons in 1980 was 1.6 gm/mile; by 1987 it drops to 0.6 gm/mile, or less than 40 percent of the 1980 rate. Note the shape of the hydrocarbon curves in Figure 4. For a given increase in average speed, the greatest impact will occur where it is needed the most, under the severely congested conditions in the range of 0 to 15 or 20 mph.

EMISSIONS

Hydrocarbon Emissions

An overview of what has been happening with hydrocarbon emissions in the Washington area is shown in Figure 5. Detailed inventories have been prepared for three data points--1972 as well as 1980 and 1987. Mobile sources are shown to be steadily decreasing, and stationary sources are increasing slightly over time. The lines cross in the middle 1980s, beyond which the mobile sources contribute less than half of the total daily hydrocarbon emissions. Figure 6 shows the hydrocarbon emissions by point, area, and mobile source for 1980 and 1987. Area sources are predicted to increase from 38 to 52 percent and mobile sources are predicted to drop from 58 to 44 percent. Figure 7 shows mobile-source hydrocarbon emissions by mode and purpose. First, the overall decrease in mobile-source emissions between 1980 and 1987 is about 40 percent--from 217 tons/day to 131 tons/day. The 1987 conditions show automobile nonwork emissions to be 79 tons, or 60 percent of the total. Work trips account for 25 percent of the total; the remaining 15 percent is due to light and heavy trucks. Finally, Figure 8 shows that four main categories of stationary sources for hydrocarbons--service stations, architectural coatings, solvents, and degreasing operations--account for two-thirds of the total emis-

Figure 8. Stationary-source hydrocarbon emissions by major type: 1980 versus 1987.

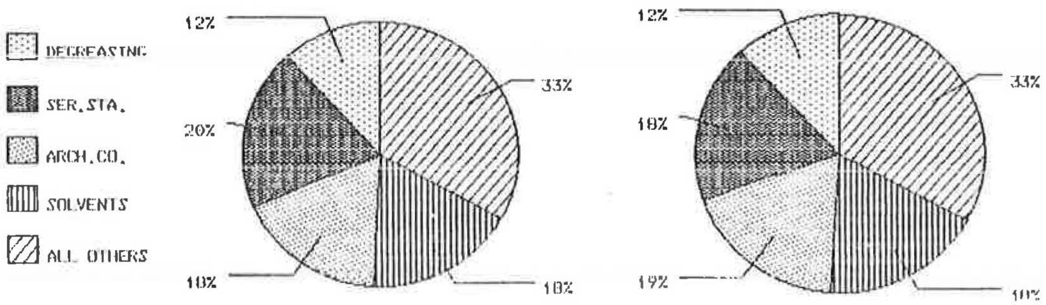
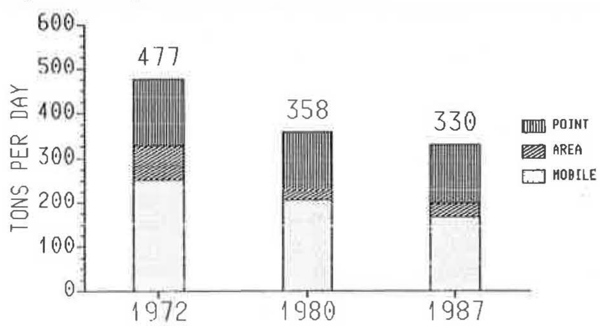


Figure 9. Nitrogen oxide emissions.



sions. The largest category, all others, accounts for 33 percent; it represents some seven or eight different sources grouped together.

Nitrogen Oxide Emissions

Figure 9 shows point, area, and mobile sources of nitrogen oxide emissions for 1972 to 1987; there is a drop of 10 percent between 1980 and 1987. This is due again mostly to the mobile-source emissions. Figure 10 shows mobile-source nitrogen oxide emissions by mode, and it indicates that trucks have a much greater effect on such emissions; they account for a third of total daily emissions in 1987. Finally, for stationary-source nitrogen oxide emissions (Figure 11), power plants are by far the largest source, accounting for more than three-fourths of the total daily stationary-source nitrogen oxide emissions.

HYDROCARBON REDUCTION REQUIREMENT

The hydrocarbon reduction requirement shown in Figure 12 is what COG has been trying to determine through the emission inventory work and what it wants to achieve in this SIP. In 1972 there was almost 600 tons/day of hydrocarbon emissions. In 1987 the level should be almost half that, or about 301 tons/day; the goal is a level of approximately 205 tons. Total emissions will be reduced from 1980 to 1987 by some 70 tons, primarily due to the reduction in the mobile-source contribution.

SENSITIVITY ANALYSES

A sensitivity analysis was performed as shown in Figure 13 to determine the effect on emissions of a 50 percent reduction in such variables as VMT; VMT and trips, because trips are so important; gasoline stations; solvents; and architectural coatings. Reduction of VMT by 50 percent causes a decrease of 22 tons in the total hydrocarbon emissions. For VMT and trips the amount decreases to 247 tons. Gasoline stations, solvents, and architectural coatings, the three primary stationary sources in the Washington area, yield a saving of 5 to 6 tons each when reduced by 50 percent. These reductions are probably more realistic attainments than those for VMT or VMT and trips. Figure 14 shows the effects of changes in travel characteristics on mobile sources. It is somewhat unrealistic to consider the effect on emissions of an increase of 5 mph in average speed regionwide, but the results are better than they were with the 50 percent reductions. A 10 percent reduction in VMT and trips and construction of the subway is probably unrealistic at this point too, but this was included as a potential action. All of these relatively modest changes in the variables reduce emissions no more than approximately 10 tons. This is an approximation of the approach that has to be taken, but the results are far lower than what is required.

MAJOR OBSERVATIONS

First, cleaner automobiles are reducing the total hydrocarbons for the 7-yr (1980-1987) period by approximately 20 percent (Figure 15). Mobile sources are decreasing by 40 percent. Mobile-source hydrocarbons shown in Figure 16 are 58 percent of the total in 1980 and only 44 percent in 1987. This is a major finding for the Washington area. Although it was noted earlier that no major polluting industry exists in this region, when the automobile contributes less than 50 percent, other sources are major contributors to the problem. Area sources increase from 38 percent to some 52 percent in the 7-yr period. Another important factor is nonwork trip emissions, which outnumber the work-trip emissions by more than 2 to 1. This means that all measures that have been considered for years that relate to the commuter trip may not be the most effective as far as reducing the total hydrocarbon and therefore the ozone. The work-trip emissions constitute about 25 percent of the total and the nonwork trip emissions, about 60 percent. The mobile-source nonwork trips are far more significant than any of the other mobile sources of hydrocarbon emissions.

Another finding that has been apparent for some time but has never been quantified is that trip-related emissions are more important than VMT emissions. It is estimated that the trip-end emissions will be approximately 48 percent, or half of the total, by 1987 and the running emissions will be

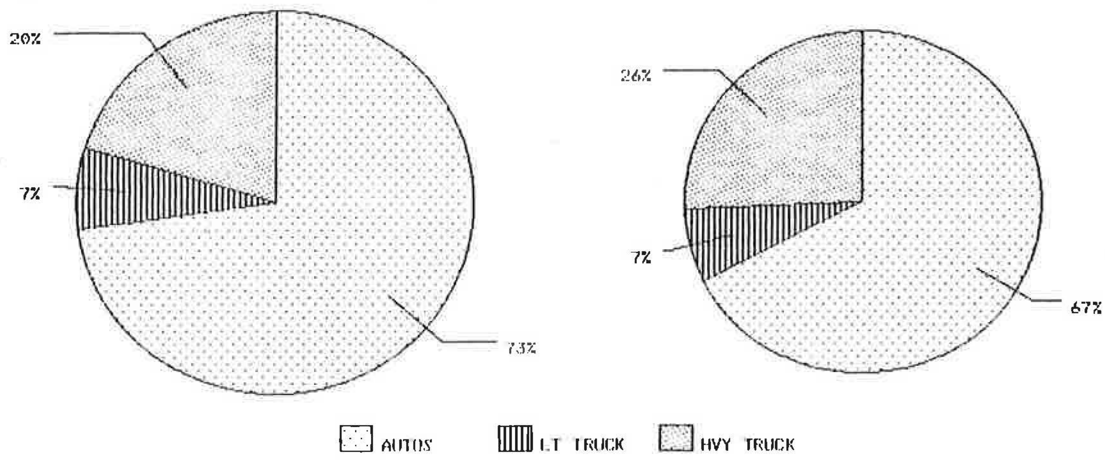


Figure 10. Mobile-source nitrogen oxide emissions by mode: 1980 versus 1987.

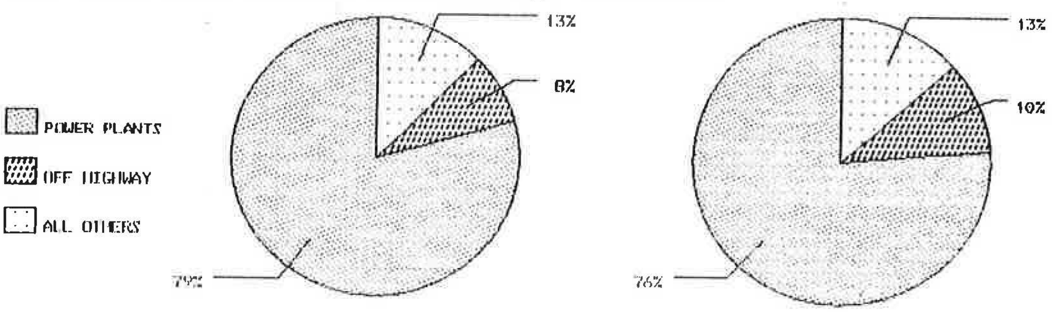


Figure 11. Stationary-source nitrogen oxide emissions by major type: 1980 versus 1987.

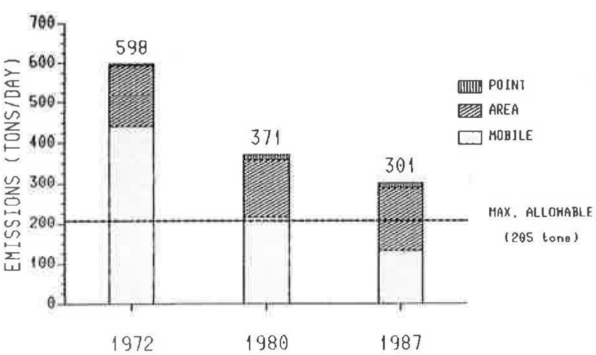


Figure 12. Hydrocarbon emission reduction required for attainment.

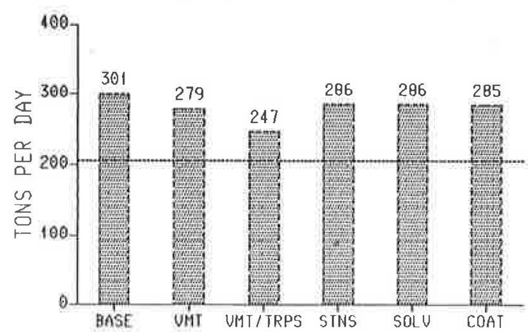


Figure 13. Sensitivity of hydrocarbon emissions to 50 percent reductions.

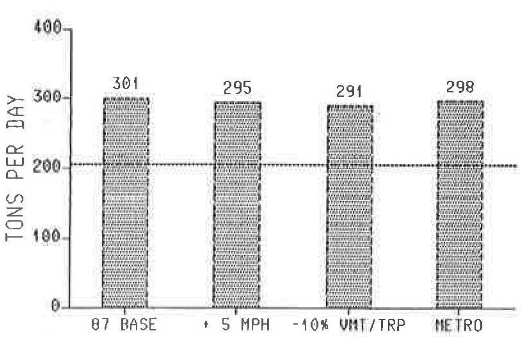


Figure 14. Sensitivity of hydrocarbon emissions to changes in travel characteristics.

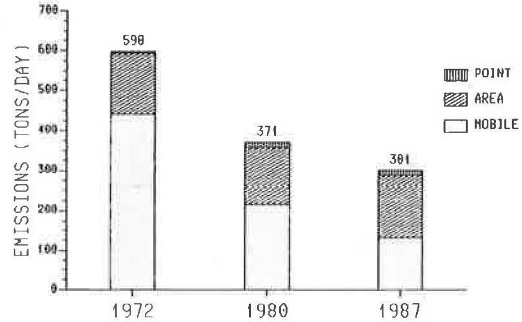


Figure 15. Hydrocarbon emissions.

Figure 16. Hydrocarbon emissions by source: 1980 versus 1987.

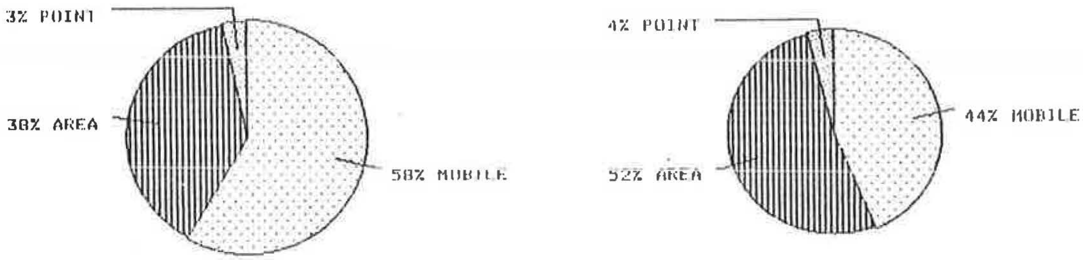
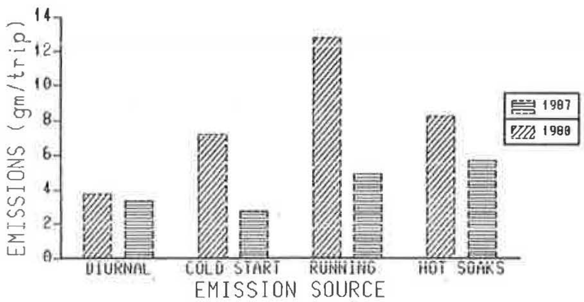


Figure 17. Automobile hydrocarbon emissions for average trip: 1980 versus 1987.



only 34 percent; these are the VMT-related emissions. There is also a category called diurnals, which are emissions that exist whether the car is started or left in the driveway. Also called the evaporative emissions, they represent about 18 percent of the total. The impact of hot soaks over time was an unexpected factor in this study. Cold starts have always been focused on as a primary source of the trip-end emissions, but hot soaks have not been studied in much detail. As can be seen in Figure 17, for the other categories of trip-related emissions--diurnal, cold start, and running--there is a significant decrease in the emissions from 1980 to 1987. There is a much less significant decrease in the proportion of hot soaks to the other categories. Thus, hot soaks represent a large percentage of total emissions. This suggests that there should be a reduction in the number of trips being made, not VMT. By doing so, a much greater reduction in total hydrocarbons and ozone can be achieved.

CONCLUSION

Once the reconnaissance-level impact analysis of the control measures had been completed, phase 2 of the program, screening the measures for implementation by the local governments, began. A more detailed impact assessment of these particular local measures is being performed, and in most cases the cost-effectiveness is being studied to determine the relative effectiveness of stationary sources versus mobile sources and to see how effective they would be on a per-ton basis. Then packages of measures are being evaluated and a final package for implementation that would be recommended to the states will be selected. Finally, in phase 3, local commitments will be obtained and the plan will be recommended.

Publication of this paper sponsored by Committee on Transportation and Air Quality.