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Analysis of the Cost Effectiveness of Motor Vehicle Inspection Programs and Selected Transportation Control Measures for Reducing Air Pollution

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ANALYSIS OF THE COST EFFECTIVENESS OF MOTOR VEHICLE INSPECTION PROGRAMS AND SELECTED TRANSPORTATION CONTROL MEASURES FOR REDUCING AIR POLLUTION

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<tr>
<td>Vehicle Operating and Time Costs</td>
<td>23</td>
</tr>
<tr>
<td>Repair Costs and Fuel Savings Offset</td>
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<td>Total Costs</td>
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<tr>
<td>Vehicle Operating and Time Costs</td>
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<tr>
<td>Repair Costs and Fuel Savings Offset</td>
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<td>Vehicle Operating and Time Costs</td>
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<td>Repair Costs and Fuel Savings Offset</td>
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<td>Total Costs</td>
<td>29</td>
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<table>
<thead>
<tr>
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<tr>
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I. BACKGROUND

The Clean Air Act directs the Administrator of the U.S. Environmental Protection Agency (EPA) to set and enforce air quality standards for the protection of the public health and welfare. EPA has established National Ambient Air Quality Standards (NAAQS), which prescribe maximum acceptable concentrations of pollutants in the ambient air over specified periods of time, as indicated in Table 1. Vehicular sources account for a significant portion of a number of these air pollutants.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO (Carbon Monoxide)</td>
<td></td>
</tr>
<tr>
<td>8-hour Average</td>
<td>9 ppm</td>
</tr>
<tr>
<td>1-hour Average</td>
<td>35 ppm</td>
</tr>
<tr>
<td>NO₂ (Nitrogen Dioxide)</td>
<td></td>
</tr>
<tr>
<td>Annual Arithmetic Mean</td>
<td>0.053 ppm</td>
</tr>
<tr>
<td>O₃ (Ozone)</td>
<td></td>
</tr>
<tr>
<td>1-hour Average</td>
<td>0.12 ppm</td>
</tr>
<tr>
<td>PB (Lead)</td>
<td></td>
</tr>
<tr>
<td>Quarterly Average</td>
<td>1.5 micrograms/cubic meter</td>
</tr>
<tr>
<td>PM-10 (Particulate&lt;10 micron diam.)</td>
<td></td>
</tr>
<tr>
<td>Annual Arithmetic Mean</td>
<td>50 micrograms/cubic meter</td>
</tr>
<tr>
<td>24-hour Average</td>
<td>150 micrograms/cubic meter</td>
</tr>
<tr>
<td>SO₂ (Sulfur Dioxide)</td>
<td></td>
</tr>
<tr>
<td>Annual Arithmetic Mean</td>
<td>80 micrograms/cubic meter</td>
</tr>
<tr>
<td>24-hour Average</td>
<td>365 micrograms/cubic meter</td>
</tr>
</tbody>
</table>

Source: California Air Resources Board

Ozone is formed when volatile organic compounds (VOCs) and nitrogen oxides (NOₓ) react in the presence of sunlight. Even low concentrations of ozone have been found to severely impair breathing and cause lung inflammation in healthy people. Reduced lung function is often accompanied by chest pain, coughing, nausea, and congestion.

Nationwide, more than one-third of VOC emissions come from transportation, with the remainder produced by industrial and commercial sources, such as painting and dry cleaning. Volatile organic compounds are a class of chemicals that includes hydrocarbons (HC).
Nitrogen oxides (NO\textsubscript{x}) are the second precursor pollutant to ozone formation, in addition to contributing to acid rain. NO\textsubscript{x} can irritate the lungs and lower resistance to respiratory inflections like the flu. Prolonged exposure to high concentrations of NO\textsubscript{x} can cause acute respiratory disease in children. The EPA has set national air quality standards for one type of NO\textsubscript{x}, nitrogen dioxide (NO\textsubscript{2}).

PM-10 is particulate matter of less than 10 microns in size (about half the diameter of a human hair). PM-10, which can be toxic because it is small enough to be breathed into human lungs, is composed of soot, dust, smoke, sulfate, and nitrate particles. Less than one-third of PM-10 pollution is caused by transportation sources. However, of that one-third, diesel exhaust is a main contributor (It is also important to note that diesel emissions are almost all in the PM-2.5 range, 2.5 microns or less, which poses a more significant health risk than PM-10.) The remainder of PM-10 pollution is caused by burning fossil fuel for manufacturing and electricity generation.

Breathing large amounts of carbon monoxide (CO) from automobile exhaust emitted in an enclosed space can be lethal. Hemoglobin, an iron-containing protein in red blood cells, is responsible for carrying oxygen to the body’s organs. CO blocks hemoglobin’s ability to carry oxygen. As a result, CO is threatening even at relatively low levels to people suffering from cardiovascular disease. At higher levels, CO can impair motor skills, visual perception, and ability to perform complex tasks. Because unburned gasoline is the primary source of carbon monoxide, the pollutant is a particular problem in areas with cold winters, when starting a cold engine requires a richer gasoline-air mixture.

Because of the removal of lead from most gasoline sold in the United States, lead emissions have decreased 98 percent since 1970. Lead is a heavy metal that accumulates in the body tissue, including blood and bones. For children and pregnant women, even low levels of lead can affect the central nervous system. At higher levels, neurological damage such as seizures, mental retardation, and behavioral disorders can appear in adults.

The EPA also sets national air quality standards for sulphur dioxide (SO\textsubscript{2}) because it is a major cause of lung disease and acid rain. However, only a small amount of the total SO\textsubscript{2} emissions come from transportation, with the majority being emitted by coal-burning electricity generation plants.

NAAQS violations in Florida have been violations of the ozone standard. As a result, our primary focus should be on reducing emissions of volatile organic compounds (VOC) and oxides of nitrogen (NO\textsubscript{x}), the principal precursors to ozone formation.

**CLEAN AIR ACT AMENDMENTS OF 1990**

The Clean Air Act Amendments of 1990 (CAA) impose much more stringent requirements on transportation than previous amendments to the Clean Air Act. State and metropolitan
transportation plans must be consistent with state air quality plans and demonstrate progress toward attainment of the NAAQS.

Areas that do not meet air quality standards are designated as nonattainment areas. These areas fall into one of six categories: transitional, marginal, moderate, serious, severe, and extreme. States with nonattainment areas must submit, as part of the State Implementation Plan (SIP), a detailed description of how the affected state and local agencies plan to attain and maintain safe air quality levels. The SIP must address each region’s approach to air quality conformity and maintenance and outline the strategies that will be used to satisfy the needs of each area.

As the severity of the air quality problem increases, requirements become more rigorous. Marginal areas must complete a series of required actions intended to reduce ozone levels. Moderate areas must meet all requirements for marginal areas, as well as additional, more stringent requirements. Beyond the moderate classification, areas may also be identified as serious (examples include Atlanta and Washington, D.C.), severe (e.g., Baltimore and Chicago), or extreme (Los Angeles). Without proper mitigation strategies, air quality could decline to the point that aggressive improvement measures could be required. Each category of nonattainment requires different time schedules and abatement measures to help ensure the NAAQS will be attained. For example, ozone (O₃) has been divided according to the criteria shown in Table 2.

<table>
<thead>
<tr>
<th>Category</th>
<th>Concentration, Not to be Exceeded More Than Once per Year (ppm)</th>
<th>Attainment Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transitional</td>
<td>&lt;0.120</td>
<td>06/30/93</td>
</tr>
<tr>
<td>Marginal</td>
<td>0.121-0.138</td>
<td>11/15/93</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.138-0.160</td>
<td>1996</td>
</tr>
<tr>
<td>Serious</td>
<td>0.160-0.180</td>
<td>1999</td>
</tr>
<tr>
<td>Severe</td>
<td>0.180-0.190</td>
<td>2005</td>
</tr>
<tr>
<td></td>
<td>0.190-0.280</td>
<td>2007</td>
</tr>
<tr>
<td>Extreme</td>
<td>0.280</td>
<td>2010</td>
</tr>
</tbody>
</table>

The Florida Department of Environmental Protection (DEP) is responsible for Florida’s SIP. DEP has developed a mobile source control program to address air pollution from motor vehicles. The program is aimed at improving air quality by reducing the amount of exhaust emissions from cars and light-duty trucks. For urban areas, the metropolitan planning organizations must (MPO) demonstrate conformity. This means Long Range Transportation Plans and Five-Year
Transportation Improvement Programs must show (through emission analyses) that they will not increase the frequency or severity of ozone violations by contributing to any increase in precursor pollutant emissions.

NONATTAINMENT AREAS IN FLORIDA

Even prior to the 1990 CAAA, U.S. EPA had cited the six Florida counties of Broward, Dade, Duval, Hillsborough, Palm Beach, and Pinellas as nonattainment areas for exceeding the NAAQS for ozone. Faced with potential federal sanctions in the form of withheld highway construction funds, the Florida Legislature enacted the Clean Outdoor Air Law (COAL), which created the Motor Vehicle Inspection Program (MVIP) in the six nonattainment counties. Under the direction of the State Department of Highway Safety and Motor Vehicles, with technical assistance provided by the Department of Environmental Regulation, private contractors began performing motor vehicle inspections in 1991.

At the time of passage of the 1990 CAAA, the six Florida counties were again identified as nonattainment areas for ozone: Dade, Broward, and Palm Beach counties comprised the Miami moderate nonattainment area; Pinellas and Hillsborough counties comprised the marginal Tampa/St. Petersburg/Clearwater nonattainment area; and Duval County (Jacksonville) was listed as a transitional nonattainment area.

Since then, air quality in all Florida counties has improved to the extent that all six of the previous nonattainment counties have earned redesignation as maintenance areas. Although all of the counties are now attaining the ozone NAAQS, the State Implementation Plan is required to demonstrate continued achievement of maintenance of acceptable air quality. More recently, in the summer of 1996, isolated ozone violations have been recorded. Although not required under the provision of the 1990 CAAA, Florida’s SIP includes the Motor Vehicle Inspection Program as one element in its program to maintain clean air.

PURPOSE OF STUDY

With the redesignation of all Florida counties as maintenance areas, there has been interest on the part of some to terminate the state’s MVIP. The past two sessions of the Florida Legislature have seen attempts to introduce legislation terminating the program. Since the emission inspection program is currently part of Florida’s SIP, if it were eliminated the state would need to implement alternative measures to demonstrate continued compliance with the ambient air quality standards. Alternative measures that might be used to maintain clean air include a wide range of transportation control measures (TCMs), generally aimed at reducing vehicle miles of travel (VMT).
The purpose of this study is to examine the relative cost effectiveness of the present MVIP, possible alternative emission inspection programs, and transportation control measures. For purposes of this study, a single county--Hillsborough--has been used as a prototype. While the methods employed are necessarily approximate, they nonetheless provide useful information about the comparative cost effectiveness of various measures. Further, although some of the characteristics of Hillsborough County have been used for purposes of creating a prototypical analysis, the major conclusions should be applicable to Florida’s other air quality maintenance counties.
II. MOTOR VEHICLE EMISSION TESTING

CHARACTERISTICS OF EMISSION TESTING PROGRAMS

Programs for inspection/maintenance (I/M) of vehicle emission control systems can be either centralized or decentralized. Centralized programs are "test only" programs where the State or a certified contractor performs the test on the vehicle emissions and, if failure occurs, the motorist uses a third party to repair the vehicle before retesting. Florida currently operates under this program. A decentralized program provides both test and repair of vehicle emissions systems by independent contractors (i.e., service stations or auto repair shops) which are licensed to conduct tests as well as perform vehicle repairs.

Technology for testing vehicle emissions includes tests conducted while the engine is idling at no load on the engine, or more sophisticated testing of the emissions while the engine is loaded and operated over a cycle of speeds while placed on a dynamometer.

In Florida, the motor vehicle inspection program (MVIP) is required by the COAL in the Ozone Maintenance Areas. The current testing procedure typically includes the following:¹

- Inspector checks to see if the vehicle is equipped with a catalytic converter and unvented fuel cap. If these items are missing or damaged, the vehicle is failed.

- While the engine is operating at idle speed, a probe with a gas analyzer is inserted into the vehicle's tailpipe to measure the levels of hydrocarbons (HC) and carbon monoxide (CO) emitted. The analyzer is computerized to compare emissions to pass/fail cut points (based on the vehicle model year) for the acceptable levels of emissions.

- If the vehicle fails the HC or CO test, it is placed on a dynamometer to run the vehicle engine at a higher speed (to ensure it is properly warmed) and then retested at idle speed. Subsequent failure will require the vehicle to be repaired and subject to retest.

Since the Florida counties previously classified as nonattainment have been reclassified as maintenance areas, an MVIP is not required by EPA. However, an MVIP is included as part of the State Implementation Plan for Florida.

Alternative Inspection/Maintenance (I/M) Testing Methods

There are a number of alternative emission inspection methods that Florida might consider. It should be recognized that the technology of emission testing is rapidly changing as existing methods are enhanced and new methods are being developed. There is considerable controversy and disagreement among experts regarding the costs and effectiveness of various technologies.
EPA's Enhanced I/M Program. An enhanced I/M testing program was proposed by the EPA in the November 5, 1992, Federal Register, as a recommended program. The recommended EPA enhanced I/M program also provides for centralized testing facilities to conduct biennial testing of 1968 and newer light-duty vehicles and trucks (gross vehicle weight $\leq$ 14,000 lbs), which include the following elements.²

- **IM240 emission testing of engine exhaust gases.** The emissions are sampled and measured while the vehicle is operated at various speeds (rather than at idle speed) on a dynamometer for a period up to 240-second test (4 minutes). In addition to measuring HC and CO emissions, oxides of nitrogen emissions ($\text{NO}_x$) are also measured. Also, the IM240 test captures the entire exhaust gases during the test, rather than a periodic small volume of gas concentration as experienced in the idle test. As typically administered, it is not normally required to conduct a full 240 minute test. The first minute or two of the test can indicate clear compliance for the majority of vehicles, for which a shortened test is adequate.

- **Purge flow test of evaporative emission canister.** Since 1971, fuel tanks on vehicles have been designed as closed systems. Excess vapors from the fuel system, under pressure, are routed to a charcoal canister. The purge test is used to ascertain that vapors trapped in the canister and fuel tank are being drawn into the engine with combustion air. If not purged, the canister will become saturated with vapors and vent them into the atmosphere, increasing HC emissions, wasting fuel, and impacting economical operation of the engine. The purge rate can only be tested while the engine is operated over a speed range (i.e., only during the IM240 driving cycle). Further, the test requires hoses, universal fittings, and a flow meter to test the process, as well as a computer to control the test process, record data, and interpret pass/fail status. Consequently, this test cannot be performed in remote situations or during the idle test. Due to difficulties in performing the purge test, there are to the best of our knowledge no current U.S. applications. (Although several states are continuing to develop alternative procedures.)

- **Evaporative system pressure test.** This test checks the fuel systems for leaks. One test method includes a pressure decay procedure that involves pressurizing the fuel system with an inert gas such as nitrogen, and measuring loss of pressure with a computer. Conducting this test requires locating the evaporative canister, removing the vapor line from the fuel tank, and connecting various hoses and fittings to a nitrogen source and computer. This test may be conducted without operating the vehicle's engine. A more sophisticated technology may alternatively be used, which includes the use of helium gas and a mass spectrometer gas analyzer.

- EPA’s enhanced I/M program also provides for periodic on-road surveillance of vehicles. Idle emission testing and testing of on-board diagnostic systems are
recommended to include ≥ 0.5% of the air quality control region's vehicles, or at least 20,000 per year.

Since EPA issued its guidelines for enhanced I/M programs, there has been widespread opposition. Due to the requirement for precision dynamometers and instrumentation, the equipment costs of an IM240 program are substantially higher than the cost of the current program. As a result, it appears that IM240 needs to be implemented as a centralized test program. The equipment costs are considered prohibitive for use by service stations and auto repair shops.

The opposition has been so strong, that in the Conference Report of the National Highway System Designation Act of 1995, a moratorium was placed on EPA’s requirement to implement its enhanced I/M program. Since then, a number of states that had either begun to implement IM240 or were planning to do so have canceled their plans.

**Acceleration Simulation Mode Tests.** Because of the widespread opposition to the I/M 240 program, over the past year there has been increased interest in alternative enhanced test, the Acceleration Simulation Mode (ASM) test. Like IM240, ASM measures NOx, in addition to CO and HC. ASM is characterized as a loaded, steady-state test. ASM is more like IM240 than it is like the current idle test. The ASM test requires the use of a dynamometer, along with instrumentation that tests a vehicle at a specified load factor and operating speed. Commonly, ASM is performed at a 50 percent load factor at 15 miles per hour (ASM 5015) or at a 25 percent load factor at 25 miles per hour (ASM2525).

Apparently, there is a considerable cost savings of ASM over IM240, as the dynamometer and test equipment are much less expensive (albeit less precise). The reduced cost of the test equipment makes it possible for a program to be operated in a decentralized mode. Even when the primary emission testing is centralized, ASM makes a decentralized repair and retesting system practical.

**Remote Sensing Devices (RSD).** Remote sensing provides the means to measure a vehicle’s exhaust gaseous emissions (HC, CO and NOx) while the vehicle is in active use on the highway. EPA perceives its application to be principally to provide on-road surveillance as part of the enhanced I/M program. Besides technical difficulties with the methodology itself, the other major limitation of the methodology is that it cannot measure the evaporative emissions (i.e., gasoline vapors) provided in the enhanced I/M program with the purge and pressure tests.

RSD measurement technology involves projecting a beam of infrared radiation from the roadside through the exhaust gases from a passing vehicle to measure the absorption of the infrared energy due to HC and CO in the exhaust. Measurement of NOx is similarly measured using an ultraviolet light beam or a light from a tunable diode laser. The system provides for measuring emissions ahead of and then behind the vehicle to assess the gas emission levels.
The system also includes freeze-frame video camera/equipment to digitize an image of the license plate number. When employed with a computer, the system can store the emission information for each vehicle monitored, along with the license plate number. This provides the means to identify and notify owners of high emission vehicles and provide follow up for further emissions testing at a centralized facility.4

**Future RSD Applications.** The application of RSD technology may also play a significant role in future I/M programs by identifying malfunctions in vehicle emissions control systems (on-board diagnostic systems), which are required beginning with 1994 vehicle models. Such malfunctions could be reported to a roadside RSD through a radio frequency transponder installed on the vehicle with the on-board diagnostics. This permits the transponder to be measured remotely, with roadside monitors, to assess the efficiency of the vehicle's emission control systems.

**Efficacy of I/M and Interpretation of I/M Test Data**

There is significant controversy reported in the scientific literature relative to the effectiveness of mandated I/M programs to achieve calculated or mathematically predicted reduction in vehicle emissions.5 This controversy is fueled by several factors. First, the accuracy of emission test procedures has been questioned. Second, there is concern that human behavioral aspects of I/M have not been adequately addressed. Finally, there are confounding factors, such as that most data used to evaluate emission reduction from I/M programs are based on California I/M programs. The California data may differ from other MVIPs.

**Emission Test Variability**

Bishop and Stedman6 evaluated the variability of emission data taken using multiple emission test data that included the following test methods: Federal Test Procedure (used to test new vehicle models), IM240 and remote sensing. A number of vehicles tested had emission control failure on one day and subsequently passed the emission test without performing any repairs. Vehicles expected to demonstrate high test-to-test variability are estimated to comprise 2 to 5 percent of the vehicle fleet. This variability appears to be larger with higher average emissions, and was most prevalent among newer vehicles with untampered closed loop emission control systems (1981 and later models). Further, vehicles with lower emissions were noted to exhibit little test-to-test variability. EPA has also long recognized that vehicles in need of repair have highly variable emission rates.
National Regulatory Perspective

EPA's *I/M Briefing Book* provides a synthesis of the regulatory perspective on testing program efficiency, degree of emission reductions expected, impact on minimizing fraud (a facet of human behavior); and costs.

EPA's position has been that only the enhanced test, including the IM240, purge flow, and pressure testing of the evaporative emission control system can effectively achieve vehicle emissions reduction when administered on a test only, centralized, biennial basis. However, it is acknowledged that even with these stringent test requirements vehicle emissions will vary from test to test on clean and dirty vehicles.

In spite of these views, the expected emission reductions (using national defaults) in areas applying the IM240 test technology along with the pressure and purge tests are projected to be 32 percent in VOC, 34 percent in CO, and 11 percent in NOx. This compares to the projection of 10% reduction of VOC with the basic tailpipe emissions test.

More recently, EPA has backed off IM240 as the only acceptable method, as it appears that ASM may also yield substantial reductions at a somewhat lower cost.

Florida MVIP Data

Data relative to vehicle emission failure rates were extracted from the Florida Department of Highway Safety and Motor Vehicle 1995 annual report and are excerpted in Table 3.

Review of these data indicate extremely low failure rates for recent model year gasoline vehicles, with the most recent model year exhibiting approximately 1 percent or less. Diesel vehicles on the other hand, show similar failure rates regardless of vehicle age. These data do suggest that it might be possible to exempt the most recent model years, from a motor vehicle inspection program and maintain a high level of emission reduction.
Table 3
Statewide Initial Emissions Inspections
Gas/Diesel Failure Rates by Model Year

<table>
<thead>
<tr>
<th>Model Year</th>
<th>Gasoline Vehicles</th>
<th>Diesel Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Inspected</td>
<td>Percent Passed</td>
</tr>
<tr>
<td>1975</td>
<td>12,950</td>
<td>73.58</td>
</tr>
<tr>
<td>1976</td>
<td>23,001</td>
<td>75.79</td>
</tr>
<tr>
<td>1977</td>
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<td>73.61</td>
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<td>1980</td>
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<td>76.45</td>
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<td>1982</td>
<td>107,639</td>
<td>74.20</td>
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<td>1983</td>
<td>152,856</td>
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<td>1984</td>
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<td>82.03</td>
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<td>1985</td>
<td>291,909</td>
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<td>340,943</td>
<td>88.06</td>
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<td>1987</td>
<td>358,331</td>
<td>91.12</td>
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<td>1988</td>
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<td>1989</td>
<td>366,002</td>
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<td>393,184</td>
<td>99.84</td>
</tr>
<tr>
<td>1995</td>
<td>96,150</td>
<td>99.90</td>
</tr>
</tbody>
</table>

III. MODELING POLLUTANT EMISSION

The U.S. Environmental Protection Agency (EPA) has promulgated computer programs to estimate the rate at which pollutants are produced by motor vehicles. The data have been used in the development of a computer model called "MOBILE" to estimate motor vehicle emissions. The model accounts for a variety of local parameters. The latest version, MOBILE5A addresses the motor vehicle emission inventory requirements stemming from the Clean Air Act Amendments of 1990 and earlier.8

DESCRIPTION OF MOBILE5A MODEL

The modeling approach used to produce a mobile source emission inventory is based on a two-step process. First, a set of emission factors (EF) is determined. Second, a set of estimates of vehicle activity is produced. The emission inventory is calculated by multiplying the results of these two steps. The model is an integrated collection of mathematical equations that estimate the grams of pollutants emitted per mile driven based on certain input variables, including vehicle age and mileage, driving conditions, average vehicle speed, ambient temperature, and rate of tampering with emission control systems.

MOBILE5A will predict fleet-average EFs for 20 years and can estimate vehicle EF for past years. MOBILE5A can be used to estimate area-wide mobile source emissions of CO, NOx, and VOC, as well as to project effects of different control strategies.

The EF represents the mass of a pollutant emitted per a defined activity rate. Mathematically it may be shown as:

\[ EF_{xx} = \frac{\text{Mass Emitted of Pollutant } xx}{\text{Activity Rate}} \]

where: \( EF_{xx} = \text{Emission Factor for Pollutant } xx \)

In the case of the MOBILE model, mass emissions of CO, NOx, and VOC are predicted as a function of VMT. MOBILE calculates vehicle emissions based on an urban test cycle, which averages 19.6 miles per hour. The EF multiplied by its activity rate (miles driven) provides estimates of the total mass emitted. The emissions estimates are performed by first determining the emissions rate of each model year making up a vehicle class, weighting the model-year-specific emission rate by the fractional usage experienced by that model year, and summing over all model years that comprise the vehicle class. In addition, a variety of corrections that are not included in the standard test cycles are used to develop the base emission rate.
EVALUATION OF MOBILE MODEL

Several limitations are associated with the MOBILE model program. Travel demand estimation procedures and air quality models were developed independently of each other, for separate purposes, and have shown a lack of coordination. Analysis of the outputs are complicated by the models’ treatment of different vehicle classification types with different algorithms. Also, EPA models assume that vehicles that fail inspections will include some type of emission repair with long-lasting benefits. McCargar and Snapp reported that long-lasting benefits cannot be demonstrated.

Critics argue that the model is difficult to understand and is insufficiently documented. Most emission inventory models relate average emission rates to traffic volumes and speeds. This approach may be subject to error since no consideration is given to vehicle operation parameters that are more closely related to emissions output. Recent studies have shown the MOBILE5A can produce reasonable emission results for freeway situations, but comparisons between observed and predicted emissions suggest that mobile sources remain under-predicted.

The requirements of the EPA assume the ability to estimate within a few percent. With current state-of-the-art methods, accuracy of plus or minus 15-30 percent in the estimation of CO, NOx, and VOC emissions is the best that can be achieved. Errors may compound in the MOBILE output. If several different model inputs have errors that are in the same direction, the errors will be compounded. An analysis of several important input parameters and how they affect the emission output is provided below. Thus, the EPA expects accuracy and precision in estimating air pollution emissions from mobile sources far beyond what is possible with current transportation planning and emissions models. The Clean Air Act Amendments of 1990 beginning with the date of enactment, required a 15 percent reduction in VOC emission over a 6-year period in moderate and worse ozone nonattainment areas.

Operating Mode and Temperature

MOBILE recognizes three operating modes (cold start, hot start, and hot stabilized) for cars and light trucks. Differences in operating mode have an impact on the emission rates. Cold start operation results in the highest grams per mile emission for all pollutants, followed by hot starts, then hot stabilized. Emissions of CO and VOC tend to be highest during cold start operations. Cold and hot start emission rates are measured during the first 505 seconds of vehicle operation. On-road cold start fractions vary for different facility types, times of day, and proximity to trip origin. Many studies have estimated the average cold start vehicle miles traveled (VMT) percentage. Kishan estimated the average cold start VMT percentage at about 20 percent and Venigalla et al. estimated 31.2 percent on a national basis. Miller et al. reported the difference in emissions due to operating mode for VOC and CO during cold conditions (32 degrees F or colder) at five and three times higher, respectively, than hot stabilized operations.
Speed

HC and CO emissions tend to be high at low speeds, and NOx emissions tend to be high at high speeds. Studies have shown all three primary pollutants are lowest when the engine is idling, and increase with vehicle acceleration. The incremental rate of increase is greatest for NOx and least for CO.19 Along with these trends, average errors of 37.8 percent in vehicle speed estimates have been reported between measured and modeled speeds when using the posted speed limits as the basis for speed estimates.20

Vehicle Miles Traveled

Mobile source emissions are estimated by multiplying EF in gram/mile by the VMT or activity rate. Emission estimates are directly related to VMT, so errors in estimating VMT produces the same amount of error in the emission estimates. VMT estimation may contain errors of 5 to 10 percent or higher, depending on the traffic counting and/or travel modeling system used.21

HILLSBOROUGH COUNTY MOTOR VEHICLE EMISSIONS

The Tampa Bay airshed, including Hillsborough and Pinellas counties, and was classified in 1990 by the EPA as a marginal nonattainment area for ozone. However, the area has recently been reclassified as a maintenance area. Nevertheless, efforts must be continued to maintain air quality, to prevent the area from falling back into nonattainment. Within Hillsborough and Pinellas counties the state operates annual, centralized, idle-mode I/M programs. The Tampa Bay area was required to produce a detailed emission inventory for the baseline year 1990 and to follow-up with a 1994 inventory.

The 1994 emissions inventory includes the use of the EPA's fleet-average emission factor model (MOBILE5A), estimates of the 1994 average daily vehicle miles traveled (ADVMT) by roadway type from U.S.DOT's Highway Performance Monitoring System (HPMS), and national average travel speeds by facility type provided by the Federal Highway Administration (FHWA). The FHWA considers HPMS estimates of VMT to be accurate to plus or minus 5 percent at a level of confidence of 95 percent.22

In Table 4, the Hillsborough County estimations of on-road emissions for 1990 and 1994 are presented. The 1990 baseline emission estimates reflect no I/M program in operation. The primary pollutants have all declined from the 1990 baseline, with NOx emissions showing the smallest reduction. These reductions have been realized even though vehicle trips have increased during this time period. Many factors contribute to emission reduction. One
primary parameter for the reduction is the date of manufacture of the average vehicle in the four years between analyses. Many of the older, more polluting vehicles have been retired and the I/M program has been successful at keeping most of the high polluters off the road since implementation of the program.
IV. COST EFFECTIVENESS OF MOTOR VEHICLE INSPECTION PROGRAMS

In this section, estimates are made to the cost effectiveness of alternative motor vehicle inspection programs in reducing mobile source emissions of volatile organic compounds (VOC) and nitrogen oxides (NOx) in Hillsborough County.

Six combinations of current MVIP technologies were chosen as the alternatives for analysis.

1. Maintain existing program
2. Use existing technology at decreased frequency (biennial)
3. IM240 (biennial)
4. IM240 plus a pressure test (biennial)
5. ASM plus a pressure test
6. Use existing program plus remote sensing

These six alternatives sufficiently represent the range of options available for a motor vehicle inspection program.

In this section, cost estimates and potential emission reductions are presented for each alternative. Costs for each of the alternatives were developed based on a variety of sources, including EPA, the current Hillsborough County MVIP contractor, and scientific literature. The different components of the costs for MVIP alternatives include inspection and oversight cost, vehicle operating and time cost, and net repair cost.

Following the analyses of costs for each of the alternatives is a cost effectiveness analysis comparing the costs of each alternative to their associated emission reductions in Hillsborough County.

ALTERNATIVE ONE: EXISTING INSPECTION PROGRAM AT CURRENT FREQUENCY (ONCE A YEAR)

This alternative consists of maintaining the current inspection program that has been in effect since 1992. The current program is a tailpipe test performed annually on all registered vehicles in Hillsborough County. The five centralized inspection stations are operated by Gordon-Darby, Inc. under contract to the State of Florida. Hillsborough County operates a basic inspection and maintenance program as defined by the EPA in the Clean Air Act Amendments of 1991. This test consists of an idle inspection (vehicle emissions are monitored while the vehicle is in an idle state), an inspection of the vehicle's catalyst, a tailpipe test, and a check of the gas cap for a vapor-tight fit.
Costs

**Inspection Costs.** The inspection costs include all capital, operating, and oversight costs associated with the inspection of vehicles under the current inspection program. The capital and operating costs include land for facilities, buildings, inspection equipment, non-labor operating costs, and labor costs. Under their contract with the State of Florida to perform tests in Hillsborough County, Gordon-Darby, Inc. receives $6 per inspected vehicle to cover all of the capital and operating costs. In Hillsborough County, the state collects an additional $4.00 per vehicle of which approximately $0.50 per vehicle is used for direct oversight of the MVIP program. The remainder of the $4 is placed in the Florida Highway Safety Operating Trust Fund and is used by the state for purposes other than oversight.** For purposes of this analyses only $6.50 of the $10 inspection fee per vehicle was included as the inspection cost because the other $3.50 does not go towards capital, operating, or oversight costs of the MVIP.

In 1994, a total of 611,838 vehicles were inspected in Hillsborough County incurring an inspection cost of $3,976,947, as shown in Table 5.

**Vehicle Operating and Time Costs.** In addition to the direct inspection costs to the vehicle owner, the driver of the inspected vehicle incurs other costs associated with the vehicle inspection. These costs include the value of the driver’s time and the cost of driving the vehicle to the inspection site. Every vehicle owner makes one round-trip to the inspection facility and the vehicle-owners of vehicles that fail inspection must have a re-inspection.

The value of the driver’s time is associated with the travel time to the inspection facility, the waiting time at the inspection facility, and the time of the inspection test. The travel time is calculated by determining the average distance of each vehicle owner to the nearest inspection station and the average speed of travel to the inspection facility. There are five inspection stations in Hillsborough County. As illustrated in Figure 1, the majority (92.5 percent) of the County’s population live within 10 miles of an inspection station. Assuming that the population is evenly distributed throughout the county, an estimation of the average travel distance of residents to an inspection facility can be accomplished by determining the average distance within each of the circles shown in Figure 1. This average distance is approximately 7 miles, or a round trip 14 miles. An approximation of the average travel speed in Hillsborough County is 19 miles per hour as provided by the Hillsborough County Metropolitan Planning Organization.** Therefore, the average travel

**The $10 inspection fee paid by vehicle-owners was adopted by the state for all six counties. The standardization of the fee was established in the interest of making the program the same cost at all locations. The $6/$4 split between the state and the contractor applies to four of the six counties with an MVIP program. In Dade County, the split between the contractor and the state is $8.20/$1.80 and in Palm Beach County it is $8.50/$1.50. Therefore, if this cost effectiveness analysis was performed for other counties in Florida the actual cost of the inspection could vary.
time to and from an inspection facility must be estimated at 44 minutes per vehicle. According to Florida's Motor Vehicle Inspection Program, the average wait time at the inspection facility is 5 minutes, and the average time of the inspection test is 2.5 minutes. Adding these three components of time yields an average time of 51.5 minutes, which includes driving time, wait time, and the duration of the test.

**Table 5**

*Inspection Costs: Maintaining Existing Program*

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection Cost</td>
<td>$6.50</td>
<td>$3,976,947</td>
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<tr>
<td>Sub-Total</td>
<td>$6.50</td>
<td>$3,976,947</td>
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<tr>
<td><em>Vehicle Operating and Time Costs</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of Time</td>
<td>$5.56</td>
<td>$3,401,130</td>
</tr>
<tr>
<td>Vehicle Operating</td>
<td>$4.37</td>
<td>$2,672,491</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$9.93</td>
<td>$6,073,621</td>
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<tr>
<td><em>Net Repair Costs</em></td>
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<td></td>
</tr>
<tr>
<td>Repair Costs</td>
<td>$10.70</td>
<td>$6,543,951</td>
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<td>Fuel Efficiency Savings</td>
<td>($5.75)</td>
<td>($3,519,994)</td>
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<tr>
<td>Sub-Total</td>
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<td>$3,023,957</td>
</tr>
<tr>
<td>Total Costs</td>
<td>$21.38</td>
<td>$13,074,525</td>
</tr>
</tbody>
</table>

The value of this 51.5 minutes of driver time was then estimated using a methodology developed by the American Association of State Highway and Transportation Officials (AASHTO). AASHTO's methodology computes value of time based on the amount of travel time and type of trip and is expressed as a percentage of the traveler's hourly income. For travel times exceeding 15 minutes, 52.3 percent of the average wage rate is multiplied against the travel time. The average hourly wage rate in Florida for 1994, as reported by the Florida Department of Labor and Employment Security, was $11.51; 52.3 percent of this hourly wage rate is $6.02. Using this hourly wage rate, the average driver's value of time in this alternative is $5.56. The total annual value of time for all drivers was estimated at $3,401,130 as shown in Table 5.
Figure 1:
Hillsborough County Motor Vehicle Inspection Stations
with 10-mile Radius Around Each Station
In addition to driver time cost, there is also a vehicle operating cost associated with MVIPs. Vehicle operating costs consist of the wear and tear costs and gasoline costs of operating the vehicle to and from the inspection facility. The 1994 Federal Income Tax reimbursement rate per vehicle mile ($0.29 per mile) was used as an approximation of average vehicle operating costs. Applying the rate of $0.29 per mile to the average round trip of 14 miles results in an annual vehicle operating cost of $4.06 per trip to the inspection facility. If all vehicle-owners make one round trip and vehicle-owners of failed vehicles make two round trips, the average annual cost per vehicle would be $4.37. The total annual vehicle operating cost would be $2,672,491, as shown in Table 5.

**Repair Costs and Fuel Savings Offset.** An additional cost in a MVIP is the repair cost for vehicles that fail the inspection minus the expected fuel savings that occur as a result of the repair. According to the Annual Report for Florida’s Motor Vehicle Inspection Program, 46,411 (7.6 percent) of vehicles failed inspection in Hillsborough County in 1994. The average repair cost for these vehicles was $141 (although the median was less than $50). Therefore, using the average, the total repair cost for Hillsborough County was $6,543,951, as shown in Table 5.

However, resulting from the repair cost is an expected fuel savings due to increased efficiencies of the vehicle after repair. The expected fuel savings was estimated using the assumptions that the average vehicle is driven 10,550 miles per year, the average cost of a gallon of unleaded gasoline is $1.11, and the average vehicle fuel efficiency is 20 miles per gallon. This results in approximately $583 per year in gasoline expenditures for each vehicle. The estimate of increased fuel efficiency due to repairs on vehicles failing the current inspection program is 13 percent, as reported by EPA. Therefore, the savings in gasoline per year per repaired vehicle was estimated to be $75.84. This information is also contained in Table 5. Fuel efficiency savings averaged annually over all vehicles yielded savings of $5.75 per vehicle.

Estimates of net repair costs of maintaining the existing program (repair costs minus fuel efficiency savings) are also contained in Table 5.

**Total Costs.** The average annual cost per vehicle for the existing inspection program in Hillsborough County is $21.38, as shown in Table 5. The total annual cost is $13,074,525. Table 5 contains a summary of inspection, driver, and net repair costs for this alternative. The total average annual cost per vehicle, $24.62, indicates the estimate of the average cost that each vehicle owner will incur per vehicle per year due to the inspection program. The total annual cost originates from all annual costs attributed to the inspection program in Hillsborough County.
ALTERNATIVE TWO: EXISTING TECHNOLOGY PROGRAM AT DECREASED FREQUENCY (ONCE EVERY 2 YEARS)

This alternative is identical to the existing program with the exception of the frequency of the inspection. The current program is on an annual basis; while this alternative calls for inspections on a biennial basis. It needs to be noted that the Environmental Protection Agency recommends that a basic inspection program (tailpipe test) be performed on an annual basis not a biennial basis.

Costs

**Inspection Costs.** The estimation of inspection costs for this alternative is also very similar to the first alternative. The differences in costs between the two alternatives are a result of the inspection being performed on a biennial basis as opposed to an annual basis. Under this alternative, only 305,919 vehicles would be inspected (half of the total vehicles inspected in Hillsborough in 1994) in one year. In addition, the inspection contractor would operate the current number of inspection locations.

Based on conversations with the current contractor in Hillsborough County, a significant portion of their costs are fixed. Therefore, because only half of the vehicles will be inspected each year the inspection cost was estimated at $10 ($9 for the contractor operating and capital cost and $1 for state oversight costs). The average annual inspection cost per vehicle is $5, and the total annual inspection cost is $3,059,190, as shown in Table 6.

**Vehicle Operating and Time Costs.** Vehicle operating and time costs are based on the same assumptions as in the first alternative. All vehicle owners would make one round-trip to an inspection station on a biennial basis. And, the owners of vehicles that failed the inspection test would make an additional round-trip to the station for retesting. The failure rate is assumed to be 12 percent. (This is higher than the current failure rate (8 percent) because the inspection is on a biennial basis). As shown in Table 6, the value of time in this alternative is $2.89 annually per vehicle and $1,770,343 for a total annual cost. The average annual operating cost per vehicle is $2.27 and total annual vehicle operating cost is $1,391,075.

**Repair Costs and Fuel Savings Offset.** As in the first alternative, average repair cost per failed vehicle are assumed to be $141. Given an annual failure rate of 12 percent, the average annual repair cost per vehicle, in this alternative, is $8.46. The total annual repair cost is $5,176,149.
Table 6
Costs: Existing Technology (Biennial)

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection Cost</td>
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<td>Sub-Total</td>
<td>$5.00</td>
<td>$3,059,190</td>
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<tr>
<td>Vehicle Operating and Time Costs</td>
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<td></td>
</tr>
<tr>
<td>Value of Time</td>
<td>$2.89</td>
<td>$1,770,343</td>
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<tr>
<td>Vehicle Operating</td>
<td>$2.27</td>
<td>$1,391,075</td>
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<td>Sub-Total</td>
<td>$5.16</td>
<td>$3,161,418</td>
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<tr>
<td>Repair Costs</td>
<td>$8.46</td>
<td>$5,176,149</td>
</tr>
<tr>
<td>Fuel Efficiency Savings</td>
<td>($4.55)</td>
<td>($2,784,253)</td>
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<tr>
<td>Sub-Total</td>
<td>$3.91</td>
<td>$2,391,896</td>
</tr>
<tr>
<td>Total Costs</td>
<td>$14.07</td>
<td>$8,612,504</td>
</tr>
</tbody>
</table>

Fuel efficiency improvements for repaired vehicles, as in the first alternative, is assumed to be 13 percent. Therefore, the average annual savings per vehicle would be $4.55 and total savings would be $2,784,253, as displayed in Table 6.

**Total Costs.** Also contained in Table 6 is a summary of inspection costs, vehicle operating and time costs, and net repair costs for this alternative in Hillsborough County. The average annual cost per vehicle would be $14.07 and the total annual cost would be $8,612,504.

**ALTERNATIVE THREE: IM240 INSPECTION PROGRAM (BIENNIAL)**

Under this alternative, the IM240 inspection program, which provides for the emissions to be sampled and measured while the vehicle is operated at various speeds on a dynamometer, would replace the current inspection program. This test measures VOC, CO, and NOx emissions. Even though the length of time for an inspection would be greater, Gordon-Darby, Inc. expects the same number of inspection stations would be needed for IM240 as for the current inspection program because vehicles would be inspected every other year rather than every year.
Costs

Inspection Costs. An estimation of the inspection cost per vehicle for an IM240 program, was determined based on fees paid by vehicle owners of different areas of the United States that currently use the IM240 inspection program. According to the EPA, the average inspection fee for an “enhanced” inspection program (IM240, plus pressure test) from a sample of 13 states was approximately $19, excluding state oversight costs. This alternative, however, includes only the IM240 test, not the pressure test. Therefore, the cost of the pressure test was deducted from the $19 test fee. Based on conversations with the current Hillsborough County contractor, the cost of the pressure test was estimated at $2, leaving $17 for the capital and operating costs of an IM240 program. The state oversight cost was estimated at $1 per vehicle for this alternative. Therefore, as shown in Table 7, the average inspection cost per vehicle would be $18 and the average annual cost per vehicle owner would be $9. The total annual inspection cost would be $5,506,542.

Vehicle Operating and Time Cost. Time costs for an IM240 program were estimated similarly to the previous alternatives. The travel time to and from the inspection facility was assumed to be 44 minutes, the same as in the first two alternatives because this alternative assumes the same number of inspection stations at the same locations. The inspection was assumed to take three minutes and the inspection wait time was assumed to be twice the inspection time or six minutes. This information was based on estimates by the EPA. Given these three components of time, total driver time per round-trip sums up to 53 minutes. Assuming that half of the vehicles would be inspected in one year and 25 percent of those inspected would return for reinspection, the average annual time cost per vehicle was estimated at $3.32, as shown in Table 7. Table 7 also contains the estimate of total annual time cost at $2,033,378.

The methodology for determining vehicle operating cost, was assumed to be identical to the previous alternative because IM240 assumes the same number of inspection stations at the same locations with vehicles being inspected on a biennial basis. The average annual costs per vehicle and total annual costs for vehicle operating costs are included in Table 7.

Repair Costs and Fuel Savings Offset. The annual repair cost for IM240 was based on an estimation that 25 percent of inspected vehicles would fail inspection in Hillsborough County for an average cost of $141 per vehicle repaired. This failure rate was based on an estimate by EPA that 20 to 30 percent of vehicles would fail the IM240 test during the first phase of the testing program.

Increased fuel efficiency was assumed to be 13 percent for each repaired vehicle, based on estimates by the EPA, producing a savings per year in gasoline costs of $75.84 per failed vehicle. If these savings were averaged over all vehicles inspected in Hillsborough County the average annual savings per vehicle would be $9.48, as displayed in Table 7.
## Table 7
Costs: IM240 (Biennial)

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inspection Cost</strong></td>
<td>$9.00</td>
<td>$5,506,542</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td>$9.00</td>
<td>$5,506,542</td>
</tr>
<tr>
<td><strong>Vehicle Operating and Time Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of Time</td>
<td>$3.32</td>
<td>$2,033,378</td>
</tr>
<tr>
<td>Vehicle Operating</td>
<td>$2.54</td>
<td>$1,552,539</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>$5.86</td>
<td>$3,585,917</td>
</tr>
<tr>
<td><strong>Net Repair Costs</strong></td>
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</tr>
<tr>
<td>Repair Costs</td>
<td>$17.63</td>
<td>$10,783,645</td>
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<tr>
<td>Fuel Efficiency Savings</td>
<td>($9.48)</td>
<td>($5,800,526)</td>
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<tr>
<td><strong>Sub-Total</strong></td>
<td>$8.15</td>
<td>$4,983,119</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>$23.01</td>
<td>$14,075,578</td>
</tr>
</tbody>
</table>

Subtracting fuel efficiency savings from repair costs, the average net repair cost per failed vehicle would be $65.16. Averaging the net repair costs over all vehicles in Hillsborough County, the annual cost would be $8.15. The total annual net repair cost for Hillsborough County would be $4,983,119.

**Total Costs.** Contained in Table 7 is a summary of all of the cost estimates under IM240, including inspection, vehicle operating and time costs, and net repair costs. The total average annual cost per vehicle would be $23.01 and total annual cost for all vehicles would be $14,075,578.

**ALTERNATIVE FOUR: IM240 INSPECTION PROGRAM/ WITH PRESSURE TEST (BIENNIAL)**

This alternative is similar to the previous alternative with the addition of the pressure test. This test adds the capability of measuring evaporative emissions in addition to tailpipe emissions for each vehicle. The pressure test would be performed independent of the IM240 test. It is estimated that it would add only one minute to the inspection time.
Costs

Inspection Costs. As in the alternative consisting only of the IM240 test, the inspection fee paid by the vehicle owner in this alternative was estimated based on fees paid by residents of different areas of the United States that currently use the enhanced (IM240 plus pressure test) inspection program. The average inspection fee for an enhanced inspection program from a sample of 13 states was approximately $19 excluding state oversight costs. As in the previous alternative, the state oversight cost was estimated at $1 per vehicle.

Contained in Table 8 is the calculation of the total inspection cost for the IM240 pressure test based on $19.00 for each test and $1.00 oversight cost for each test, for a total of $20.00 per vehicle on a biennial basis. The annualized cost for a vehicle owner would be $10 per vehicle.

Vehicle Operating and Time Cost. Driver costs in this alternative were estimated in a similar way as the previous alternatives. The travel time to and from the inspection facility was assumed to be 44 minutes. The inspection was assumed to take four minutes, and the inspection wait time was assumed to be twice the inspection time or eight minutes. This information was based on estimates by the EPA that assumed that the pressure test would take an additional one minute to administer. Given these three components of time, total driver time per round-trip sums up to 56 minutes. Using the same methodology to calculate value of time as in the other alternatives, the average value of time per vehicle was estimated at $3.68, as shown in Table 8. Table 8 also contains the estimate of total annual cost for the value of time at $2,251,602.

Vehicle operating costs were estimated similarly to the IM240 alternative. Every vehicle was assumed to make at least one round-trip to the inspection station biennially. In addition, vehicles that either fail the IM240 or pressure test would make an additional round-trip for retesting. The average annual operating costs per vehicle and total annual operating costs are included in Table 8.

Repair Costs and Fuel Savings Offset. The annual repair cost for this alternative was separated into two cost areas related to the IM240 test and the pressure test. These are separated because each test has an estimated failure rate associated with it, and the estimate of average repair cost is different depending on which test a vehicle fails. As in the IM240 alternative, it was estimated that 25 percent of tested vehicles would fail the IM240 test, and the average repair cost would be $141. For the pressure test, the failure rate was estimated at 6 percent with an average repair cost of $38 for each vehicle that fails the test, as estimated by the EPA. Information on the total repair costs for each inspection test is contained in Table 8.
Increased fuel efficiency is also dependent on which inspection test a vehicle fails. Vehicles that fail the IM240 test could expect an average increase of 13 percent in fuel efficiency after repairs, producing an average savings per year per repaired vehicle in gasoline of $75.84. An increase in fuel efficiency of 6 percent would be associated with the pressure test, as reported by EPA, producing an annual gasoline savings per vehicle of $35.01 for each repaired vehicle.36

The average annual net repair cost per vehicle for each type of test and the total annual net repair cost for Hillsborough County is contained in Table 8.

Table 8
Costs: IM240 + Pressure

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection Cost</td>
<td>$10.00</td>
<td>$6,118,380</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$10.00</td>
<td>$6,118,380</td>
</tr>
<tr>
<td>Vehicle Operating and Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of Time</td>
<td>$3.68</td>
<td>$2,251,602</td>
</tr>
<tr>
<td>Vehicle Operating</td>
<td>$2.66</td>
<td>$1,627,061</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$6.34</td>
<td>$3,878,663</td>
</tr>
<tr>
<td>Net Repair Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IM240 Repair Cost</td>
<td>$17.63</td>
<td>$10,783,645</td>
</tr>
<tr>
<td>IM240 Fuel Efficiency Savings</td>
<td>($9.48)</td>
<td>($5,800,526)</td>
</tr>
<tr>
<td>Pressure Test Repair Cost</td>
<td>$1.14</td>
<td>$697,495</td>
</tr>
<tr>
<td>Pressure Test Fuel Efficiency</td>
<td>($1.05)</td>
<td>($642,520)</td>
</tr>
<tr>
<td>Savings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$8.24</td>
<td>$5,038,094</td>
</tr>
<tr>
<td>Total Costs</td>
<td>$24.58</td>
<td>$15,035,137</td>
</tr>
</tbody>
</table>

Total Costs. Also contained in Table 8 is a summary of all of the costs under this alternative, including inspection, vehicle operating and time and net repair costs. The average annual cost per vehicle would be $24.58 and total annual cost would be $15,035,137.
ALTERNATIVE FIVE: ASM INSPECTION PROGRAM WITH PRESSURE TEST (BIENNIAL)

Under this alternative, the ASM test would be administered with the same pressure test that would be administered in the previous alternative. As described earlier, the ASM test measures VOC, CO, and NOx emissions (similar to IM240). The ASM test was developed as a lower cost alternative to IM240. However, the test is not as effective in identifying polluting vehicles, and it produces more false-failures than IM240.

In order to compare this alternative to IM240, the ASM test presented in this alternative assumes a similar false-failure rate to the IM240 test presented in previous alternatives. This produces an emission reduction level 70 percent as effective as the IM240 test.

Costs

Inspection Costs. The inspection cost for an ASM inspection program with a pressure test was estimated based on conversations with the current inspection contractor in Hillsborough County. Operating and capital costs were estimated at $12 for ASM and $2 for the pressure test per vehicle. Similar to the other alternatives that would be administered on a biennial basis, state oversight costs were estimated at $1 per vehicle.

Contained in Table 9 is the calculation of the total inspection cost for the ASM plus pressure test alternative based on a test cost of $15 per vehicle on a biennial basis. The annualized cost for a vehicle owner would be $7.50.

Vehicle Operating and Time Costs. Time costs in this alternative were estimated in a similar way as the previous alternatives. The travel time to and from the inspection facility was assumed to be 44 minutes, the same as in the other alternatives because this alternative assumes the same number of inspection stations at the same locations. The inspection was assumed to take four minutes, and the inspection wait time was assumed to be twice the inspection time or eight minutes. Given these three components of time, total driver time sums up to 56 minutes. Using the same methodology to calculate value of time as in the other alternatives, the average annual time cost per vehicle would be $3.40 as shown in Table 9. Table 9 also contains the estimate of total annual cost for the value of time at $2,079,724.

Vehicle operating costs for this alternative, are also similar to the IM240 alternative because the ASM alternative assumes the same number of inspection stations at the same locations with vehicles being inspected on a biennial basis. The average annual operating cost per vehicle and total annual vehicle operating costs are included in Table 9.
Table 9  
Costs: ASM + Pressure

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection Cost</td>
<td>$7.50</td>
<td>$4,588,785</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$7.50</td>
<td>$4,588,785</td>
</tr>
</tbody>
</table>

*Vehicle Operating and Time Costs*

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of Time</td>
<td>$3.40</td>
<td>$2,079,724</td>
</tr>
<tr>
<td>Vehicle Operating</td>
<td>$2.45</td>
<td>$1,502,858</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$5.85</td>
<td>$3,582,582</td>
</tr>
</tbody>
</table>

*Net Repair Costs*

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASM Repair Cost</td>
<td>$10.58</td>
<td>$6,470,187</td>
</tr>
<tr>
<td>ASM Fuel Efficiency Savings</td>
<td>($5.69)</td>
<td>($3,480,316)</td>
</tr>
<tr>
<td>Pressure Test Repair Cost</td>
<td>$1.14</td>
<td>$697,495</td>
</tr>
<tr>
<td>Pressure Test Fuel Efficiency</td>
<td>($1.05)</td>
<td>($642,520)</td>
</tr>
<tr>
<td>Savings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-Total</td>
<td>$4.98</td>
<td>$3,044,846</td>
</tr>
<tr>
<td>Total Costs</td>
<td>$18.33</td>
<td>$11,216,213</td>
</tr>
</tbody>
</table>

*Repair Costs and Fuel Savings Offset.* The annual repair cost for this alternative was separated into two cost areas related to the ASM test and the pressure test. These are separated because each test has an estimated failure rate associated with it, and the estimate of average repair cost is different depending on which test a vehicle fails. It was estimated that 15 percent of tested vehicles would fail the ASM test, and the average repair cost would be $141. For the pressure test, the failure rate was estimated at 6 percent with an average repair cost of $38 for each vehicle that fails the test, as estimated by the EPA. Information on the total repair costs for each inspection test is contained in Table 9.

Increased fuel efficiency is also dependent on which inspection test a vehicle fails. Vehicles that fail the ASM test could expect an average increase of 13 percent in fuel efficiency after repairs producing an average savings per year per repaired vehicle in gasoline of $75.84. An increase in fuel efficiency of 6 percent would be associated with the pressure test, as reported by EPA, producing an annual gasoline savings per vehicle of $35.01 for each repaired vehicle.
The average annual net repair cost per vehicle for each type of test and the total annual net repair cost for Hillsborough County is contained in Table 9.

**Total Costs.** Also contained in Table 9 is a summary of all of the costs under this alternative, including inspection, vehicle operating, time cost, and net repair costs. The average annual cost per vehicle would be $18.33 and total annual cost would be $11,216,213.

**ALTERNATIVE SIX: CURRENT INSPECTION PROGRAM SUPPLEMENTED WITH LIMITED REMOTE SENSING DEVICES**

In this alternative, remote sensing devices (RSD) would be used to supplement the current annual inspection program. One mobile team with an RSD van operator, a Highway Patrol officer, and inspectors would move from one location to another on a daily basis throughout Hillsborough County. Using the remote sensing devices, high-emitting vehicles would be identified and pulled over by Highway Patrol officers. A visual inspection would be immediately performed on the vehicle to identify tampering. Failing vehicles would be required to be repaired and retested.

The added advantage of the RSD supplement is the ability to perform immediate visual inspections, thereby creating a tampering deterrence. It is a deterrent because an under-the-hood inspection would be seen by all traffic that passes by the remote site.

**Costs**

Since remote sensing would be used as a supplement to the existing inspection program, the cost estimates would include all costs associated with current inspection program plus additional the additional labor and capital costs of the mobile team and net repair costs for vehicles failed by the mobile inspection team.

An estimate of the labor and capital cost of the mobile team was taken from a study prepared by Sierra Research, Inc., for the EPA. This study estimated that to outfit each mobile team would cost $556,954 annually, as shown in Table 10. Sierra Research estimated that six mobile teams would be needed to adequately cover the study area (the Los Angeles Basin) inspecting 64,000 vehicles (one percent) annually. Using this methodology, it was estimated that one mobile team would be adequate to annually inspect one percent of total vehicles in Hillsborough County. One mobile team could annually visually inspect approximately 10,700 vehicles.

Net repair costs for vehicles failing the remote inspection was estimated based on an average repair cost of $141 for all vehicles (the same repair cost as for vehicles inspected at the fixed facility). The increased fuel efficiency for the repaired vehicles was estimated at 13 percent which would create an annual savings of $75.84. Therefore, the total repair cost and the fuel efficiency
savings was estimated to be $1,508,700 and $811,530, respectively, as shown in Table 10. Total annual cost for this alternative was estimated at $14,328,649.

### Table 10
Cost: Existing Program + Remote Sensing

<table>
<thead>
<tr>
<th>Type of Cost</th>
<th>Avg. Annual Cost per Vehicle</th>
<th>Total Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Program Cost</td>
<td>$21.38</td>
<td>$13,074,525</td>
</tr>
<tr>
<td>RSD Cost</td>
<td>$0.91</td>
<td>$556,954</td>
</tr>
<tr>
<td>Repair Cost</td>
<td>$2.47</td>
<td>$1,508,700</td>
</tr>
<tr>
<td>Fuel Efficiency Savings</td>
<td>($1.33)</td>
<td>($811,530)</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$23.43</td>
<td>$14,328,649</td>
</tr>
</tbody>
</table>

**COST EFFECTIVENESS COMPARISON OF INSPECTION ALTERNATIVES**

**Emission Reductions**

Contained in Table 11 are the estimates of annual emission reductions for volatile organic compounds (VOC) and oxides of nitrogen (NOx) for each of the vehicle emission inspection alternatives. The reductions are represented as percentage reductions of each pollutant and the number of tons reduced in one year. For all of the alternatives except the alternative using remote sensing devices, the estimates of emission reductions were based on national defaults calculated through the EPA’s Mobile 5A Model with an adjustment for the amount of travel in Hillsborough County by vehicles that are not required to be inspected (e.g., vehicles that enter or pass through Hillsborough County from other counties). To estimate this amount of travel, FDOT estimated the percent of trips made by vehicles that are not inspected. The estimate in 1995 was that 10.5 percent of trips were by vehicles that were not inspected. Assuming that these non-inspected vehicles represent an average cross-section of the Hillsborough County fleet, estimated emission reductions were adjusted down by 10.51 percent.

As shown in Table 11, the current inspection program annually reduces VOC emissions by 9 percent. NOx emissions is reduced by 1.34 percent. The current test does not measure for NOx. However, because of repairs in the vehicles that fail because of other pollutants, there are some reductions in NOx due to the inspection program.
The annual emission reductions for the alternative reflecting the existing technology on a biennial basis, as shown in Table 11, would be less than those for the current inspection program on an annual basis for both VOC and NO$_x$.

Annual NO$_x$ reductions in the IM240 alternative would be much greater than in the current program. This jump in reduction can mainly be attributed to the fact that the IM240 test measures for NO$_x$. Annual VOC reductions would also increase in this alternative.

By adding the pressure test to IM240, annual VOC reductions would increase by 8 percent in comparison to IM240 by itself, but annual NO$_x$ reductions would remain constant. This result is due to the fact that the pressure test does not measure NO$_x$ emissions.

Under the ASM plus pressure alternative, VOC emissions would be reduced annually by approximately 18 percent. For NO$_x$, the annual reductions would be 7 percent for this alternative. The final alternative, as shown in Table 11, would result in an annual reduction of 10.85 percent in VOC and 1.94 percent in NO$_x$. Because this alternative contains the existing program plus the supplement of remote sensing devices, it would create a net increase in reduction of 1.9 percent and 0.6 percent of VOC and NO$_x$ over the current inspection program.

### Table 11
**Annual Emission Reductions**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Percent Annual Reduction of VOC</th>
<th>Annual Reduction of VOC (in tons)</th>
<th>Percent Annual Reduction of NO$_x$</th>
<th>Annual Reduction of NO$_x$ (in tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Existing Inspection Program</td>
<td>8.95</td>
<td>1,724</td>
<td>1.34</td>
<td>298</td>
</tr>
<tr>
<td>2. Existing Technology (Biennial)</td>
<td>7.16</td>
<td>1,379</td>
<td>1.07</td>
<td>239</td>
</tr>
<tr>
<td>3. IM240</td>
<td>14.32</td>
<td>2,759</td>
<td>9.84</td>
<td>2,187</td>
</tr>
<tr>
<td>4. IM240 Plus Pressure</td>
<td>22.69</td>
<td>4,371</td>
<td>9.84</td>
<td>2,187</td>
</tr>
<tr>
<td>5. ASM Plus Pressure</td>
<td>18.39</td>
<td>3,543</td>
<td>6.89</td>
<td>1,531</td>
</tr>
<tr>
<td>6. Existing Program Plus Remote Sensing</td>
<td>10.85</td>
<td>2,090</td>
<td>1.94</td>
<td>431</td>
</tr>
</tbody>
</table>

### Cost Effectiveness

Table 12 contains the total costs and cost effectiveness measures for each of the vehicle inspection alternatives. The cost effectiveness measures represent the annual cost to reduce pollutants by one ton. The pollutants are a sum of VOC and NO$_x$. The methodology of summing the reductions...
of VOC and NO\textsubscript{x} is based on the cost effectiveness analysis performed by Sierra Research, Inc.'s report.\textsuperscript{40} In this report, VOC and NO\textsubscript{x} emissions are combined with one-seventh of CO emissions, thereby discounting the air quality degradation associated with CO emissions. For this report, VOC and NO\textsubscript{x} emissions were used without CO because these two pollutants combined with sunlight produce ambient ozone which is the most critical pollution issue in the Tampa Bay airshed.

As previously noted, the IM240 and ASM alternative are estimated to reduce annual emissions to a greater extent. In addition, the annual cost effectiveness measures for these alternatives are greater than for the current program. Of all of the alternatives, the alternative containing the ASM test plus the pressure test has the lowest (i.e., the best) annual cost effectiveness measure at $2,210 per ton of emissions. However, the IM240 plus pressure alternative is very close in cost effectiveness at $2,293 per ton of emissions.

<table>
<thead>
<tr>
<th>Table 12</th>
<th>Annual Cost Effectiveness of Inspection Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative</td>
<td>Annual Reduction of VOC and NO\textsubscript{x} (tons)</td>
</tr>
<tr>
<td>1. Existing Inspection Program</td>
<td>2,022</td>
</tr>
<tr>
<td>2. Existing Technology (Biennial)</td>
<td>1,618</td>
</tr>
<tr>
<td>3. IM240</td>
<td>4,946</td>
</tr>
<tr>
<td>4. IM240 Plus Pressure</td>
<td>6,558</td>
</tr>
<tr>
<td>5. ASM Plus Pressure</td>
<td>5,074</td>
</tr>
</tbody>
</table>

A further refinement of the two most cost-effective alternatives (IM240 plus pressure and ASM plus pressure) would be to exempt vehicles of the three newest model years from the biennial inspection process. As shown in Table 3 on page 11, vehicles of model years 1993, 1994, and 1995 represent a very small percentage of the vehicles that fail the current inspection program. If the same distribution of failures by model year is assumed for these two alternatives, eliminating from inspection vehicles of the newest three model years would decrease reductions in emissions to 4,336 annual tons of VOC and 2,169 annual tons of NO\textsubscript{x} for the IM240 plus pressure alternative, and to 3,515 annual tons of VOC and 1,518 annual tons of NO\textsubscript{x} for the ASM plus pressure alternative.

This decrease in reductions in emissions must be balanced against the decrease in annual cost that results from eliminating these vehicles from inspection. The owners of these newer vehicles would not incur the expenses associated with the inspection program. Under this option, the total annual
This decrease in reductions in emissions must be balanced against the decrease in annual cost that results from eliminating these vehicles from inspection. The owners of these newer vehicles would not incur the expenses associated with the inspection program. Under this option, the total annual cost would be $13,102,908 for the IM240 plus pressure alternative and $9,619,815 for the ASM plus pressure alternative. The annual cost effectiveness would be lower (i.e., better) than any of the previously presented alternatives at $2,014 per ton for IM240 plus pressure and $1,911 per ton for ASM plus pressure.
V. COST EFFECTIVENESS OF TRANSPORTATION CONTROL MEASURES

In this section, estimates are made of the effectiveness of transportation control measures (TCMs) in reducing mobile source emissions of volatile organic compounds (VOC) and nitrogen oxides (NOx). Current transportation planning models do not permit accurate estimation of the impacts of most transportation control measures. As a result, the available literature on the effectiveness of TCMs is largely anecdotal and related to the characteristics of specific areas. Generalizing results to Hillsborough County is problematic, but it represents the only available option. The results reported here give a reasonable picture of the relative cost effectiveness of the TCMs in reducing emissions, but the absolute cost and emission-reduction values should be used with caution. This report does not evaluate the cost effectiveness of TCMs in reducing congestion, nor are the benefits of reduced congestion included in the calculations.

Most TCMs are actions taken to reduce the length or number of trips by single-occupant vehicles. These actions are usually taken with the primary objective of reducing congestion by reducing the number of vehicles on the road but they also result in reduced vehicle emissions. Most TCMs are targeted primarily at work trips, which typically are about 30 percent of total trips, while vehicle inspection programs contribute to reduced emissions for all trips.

There are also TCMs that attempt to reduce emissions, not by reducing the number of vehicles on the road, but by reduced idling and increased average speed, which generally also results in reduced vehicle emissions.

The major categories of TCMs involve either incentives to change travel patterns or disincentives to continue current travel patterns. The disincentive category consists primarily of strategies that make it relatively more expensive or difficult to use an automobile, especially during peak hours. These include increases in the cost of parking, reductions in the supply of parking, increased tolls during peak hours (congestion pricing), and increased taxes based on consumption of fuel or miles driven. Another disincentive TCM is an emissions fee that varies according to emission levels. It is targeted directly at emissions and, as is generally the case with direct actions, is likely to be more efficient than indirect measures in achieving air-quality objectives.

Most TCMs involve incentives to use other modes of travel or to change time of day of travel. The incentives to change modes include transit improvements, park-and-ride programs, improved accommodations for bicycles and pedestrians, and provision of ridesharing services and accompanying incentives such as high-occupancy-vehicle (HOV) lanes and special parking privileges. Incentives to change travel times include alternative work schedules (e.g., programs such as compressed work weeks, flexible hours, staggered hours, and telecommuting).

There also is a group of TCMs that involve mechanical or technological fixes, such as the coordination of traffic signals.
The TCMs in the disincentive category can be quite effective if the price or fee is set high enough. Travel in single-occupant vehicles can be reduced significantly if the use of the automobile is made sufficiently expensive or difficult. However, the use of these TCMs is severely constrained by their lack of public and political acceptance. The TCMs in the incentive category have much greater public acceptance but are not nearly as effective. Each TCM tend to reduce emissions less than one percent.

Many studies done across the U.S. have evaluated the effectiveness of TCMs. As noted earlier, these studies have typically involved the reporting of anecdotal experiences of specific programs. The absence of suitable transportation planning models to deal with TCMs makes it difficult to make inferences from other experiences. Probably the most generalizable study was performed for the National Association of Regional Councils by Apogee Research Inc. This study developed generalized estimates of VMT and VOC reductions for a typical large urbanized area.

The TCMs that seem to have the greatest potential for reducing emissions and being politically acceptable in Hillsborough County, and that have been examined in more detail, are listed below. (Parking pricing is not as politically acceptable as the other TCMs but it has been included to illustrate the cost effectiveness of disincentive TCMs).

- Parking pricing for work trips
- HOV lanes
- Telecommuting
- Compressed work week
- Flexible work hours
- Staggered work hours
- Traffic signal optimization
- Ridesharing
- Park-and-ride lots

A serious concern with many of these TCMs is the long-term adjustment that drivers may make in response to them. If TCMs result in improvements in travel conditions through increases in speed and reductions in congestion, they may induce more travel. The end result could be higher VMT, cold starts, and emissions than before the TCMs were implemented, although a recent report does suggest that increases in highway capacity result in a net reduction in emissions. Nonetheless, it must be kept in mind that TCMs for the most part are designed to improve mobility, not reduce emissions. This analysis looks solely at the impacts TCMs have on emissions; it does not consider other benefits that TCMs may confer.
### Table 13
Daily Area-Wide Percent Reduction Due to TCMs

<table>
<thead>
<tr>
<th>TCM</th>
<th>VMT (Percent)</th>
<th>Trips (Percent)</th>
<th>VOC Emissions (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestion pricing¹</td>
<td>5.0</td>
<td>3.8</td>
<td>8.2</td>
</tr>
<tr>
<td>Parking pricing:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-work²</td>
<td>4.2</td>
<td>5.4</td>
<td>4.6</td>
</tr>
<tr>
<td>work³</td>
<td>3.0</td>
<td>2.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Emissions/VMT tax</td>
<td>0.4</td>
<td>0.7</td>
<td>4.1</td>
</tr>
<tr>
<td>HOV lanes</td>
<td>1.4</td>
<td>0.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Telecommuting⁴</td>
<td>1.1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Rail transit improvements</td>
<td>1.0</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Compressed work week⁵</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Traffic signal optimization</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>Area-wide ridesharing</td>
<td>0.4</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Park-and-ride lots</td>
<td>0.5</td>
<td>0.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Bicycle/pedestrian facilities</td>
<td>&lt;0.1</td>
<td></td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

¹ Based on an additional toll of 15 cents per mile.
² Based on $0.60 per hour up to maximum of $3.00 per day for all non-residential parking in county currently below those rates.
³ Based on a parking rate increase of $2.00 per day.
⁴ Based on 10 percent of workforce telecommuting two days per week.
⁵ Based on 10 percent of workforce on a 4/40 compressed work week (four 10-hour days each week).


Note: According to Apogee these estimates are the “maximum reasonable potential” for a typical large urban area.

From an emissions standpoint, it is very important not only to reduce VMT, but also to eliminate trips, because trip end emissions (from cold starts and hot soaks) are a substantial component of total emissions. This may be especially important when considering TCMs that reduce VMT but may induce new trips. The emissions from the new trips could easily offset the savings from the reduced VMT. According to a report prepared for the U.S. EPA⁴³ the proportion of trip end emissions is:
Trip end emissions = 75 percent of all emissions on a 5-mile trip
= 61 percent of all emissions on a 10-mile trip
= 45 percent of all emissions on a 20-mile trip

The discussions of each TCM that follow include a variety of cost and benefit data from various studies. Some studies include reduced vehicle operating costs, for example, as a benefit of some TCMs, with the result that there is a “negative cost” of reducing emissions. Other studies use just the implementation cost of TCMs to calculate the cost of reducing emissions. In this study, it is assumed that if the benefits to a driver of ridesharing, for example, or other TCMs are greater than the costs, the driver would already be ridesharing. It also is assumed that changes in travel patterns and modes caused by the implementation of TCMs will occur near the margin. That is, it is assumed that the benefits of reduced vehicle operating costs, etc., attributable to ridesharing are equal to the costs of increased travel time, reduced convenience, etc. Also, transfers of money from individuals to the government are not counted as costs, such as would occur if public parking prices were increased. Therefore, the costs that were calculated for the reduction of emissions are based on the economic or “real” costs of implementing the TCMs.

PARKING PRICING

Increasing the cost of parking makes driving more expensive relative to other modes. The purpose is to discourage single occupant vehicle (SOV) drivers. The policy can be aimed at all drivers or it can be targeted at peak-hour drivers, at SOV drivers, or at long-term parkers (i.e., work commuters). If increased parking prices are in effect only during peak hours, the effect, in part, is to shift trips to non-peak hours, in addition to reducing total SOV trips. If higher prices are set for long-term use, one consequence is to free up more parking for short-term parkers, which may actually result in an increase in total trips and VMT. It is likely that these new trips would be at non-peak hours and, therefore, peak-hour congestion would be reduced.

Government can most easily affect the price of public parking (both on- and off-street), over which it has direct control. It may be limited in its ability to affect private parking prices, though a general tax on parking is one approach that has been used. The ideal setting for this TCM is a dense central business district (CBD) that has extensive transit service, limited private parking, a small proportion of through traffic, a small proportion of employer-paid parking, and little competition from suburban office development. San Francisco and Boston are good examples. In other cities, as a rule, the danger of harming downtown economic development makes it politically very difficult to implement policies that make CBD parking more expensive or less convenient. Other issues to consider include the impact on low-income workers and the possibility of parkers spilling over into residential areas.

 Nonetheless, this TCM has been implemented in numerous cities, including Madison, Seattle, San Francisco, Chicago, and Eugene. In Madison it was estimated that a one dollar peak-hour parking surcharge resulted in 5 to 8 percent of customers at the four public parking lots switching
to transit. An analysis for Phoenix suggested that in 1995 a county-wide average price increase of $1.50 per day for those who currently pay to park would affect only a third of the employees and would reduce trips 0.48 percent and VMT 0.56 percent, while peak-hour speeds would increase 0.67 percent and off-peak speeds would increase 0.13 percent. A similar study for the California Air Resources Board suggested that instituting a minimum daily parking fee of $3.00 would reduce VMT, trips, and emissions between 2 and 3 percent.

The Phoenix study concluded that the public cost of administering and enforcing a parking program and providing the necessary additional transit service would be more than offset by the additional revenue generated by the $1.50 daily increase in parking fees, with the net result being an annual saving of $12.41 per registered vehicle. There also would be additional revenues flowing to the private sector amounting to $216.85 per vehicle per year. Individual costs for the higher parking fees and increased transit usage minus savings resulting from reduced vehicle operating costs would result in a net increase in individual costs of $298.39 per vehicle per year. The combined total cost of the parking program would be $69.13 per registered vehicle per year in 1995.

A report prepared by Cambridge Systematics says that in the early 1980s the costs of administering and enforcing comprehensive pricing programs in Eugene and Santa Cruz were between $30,000 and $50,000.

HIGH-OCCUPANCY-VEHICLE LANES

HOV lanes are lanes on limited-access and arterial roadways that are reserved for all or part of the day (often during peak hours only) for buses and for other vehicles carrying a minimum number of persons (often a minimum of three persons). These lanes often are reversible; that is, they may be restricted to inbound traffic in the morning and outbound traffic in the evening. By reducing travel time and costs for high-occupancy vehicles, they are an obvious encouragement to ridesharing and the benefits that come with a ridesharing program. They also promote the use of transit. They often are constructed in coordination with park-and-ride lots and ridesharing programs. They typically reduce travel time between 1.5 and 2.0 minutes per mile.

They are one of the more effective of the incentive TCMs, but they are expensive to construct. If existing lanes are converted to HOV lanes, the remaining lanes become more congested, defeating much of the purpose of the HOV lanes. There also usually is strong public opposition to converting existing lanes to HOV lanes. If new lanes are built especially for HOVs, the reduced congestion on the other lanes will induce some additional travel, offsetting at least some--if not all--of the reduction in trips and VMT caused by persons switching to HOVs. Another possibility is that HOV lanes will cause some transit users to switch to car pools.

HOV lanes are common in large urban areas. The San Francisco Bay area had 77 miles of HOV lanes in 1990 and had plans to have 140 miles by 1995 and 330 miles by 2005. San Francisco
projects that this extensive system in 2005 will result in reductions of 1.0 percent in VMT and 2.3 percent in work-trip VOC emissions. In 1990 Houston had 47 miles of HOV lanes with plans for 48 more miles. Houston’s cost of construction, including adjoining park-and-ride lots and transit centers, was $8.7 million per mile. The cost of HOV facilities varies greatly depending on right-of-way costs, interchange modifications needed, and the extent of accompanying facilities provided.

TELECOMMUTING

Telecommuting is simply working at home or at a nearby telecommute center, thereby avoiding the round-trip commute to work. Some types of jobs are not suitable for telecommuting, such as many manufacturing and service-sector jobs; office jobs are generally the most suitable. A study in Philadelphia by COMSIS Corporation estimated that 15.6 percent of the jobs in the region would be suitable for telecommuting. Another study suggests that if an employer offers a telecommuting option, 32 percent of the employees will telecommute an average of 1.8 days per week. There is some concern that telecommuting may reduce the number of persons participating in ridesharing programs. Also, some trips that previously were linked with the commute trip—such as day care trips—may still need to be made on the telecommute work day.

There is little or no governmental cost in implementing a telecommuting program, unless local government undertakes a public information campaign to encourage the adoption of such programs. The primary cost, although relatively minor, is the administrative and employee-training cost a firm would incur. This cost may be more than offset by employer savings on parking subsidies and, possibly, office space. It also is argued that telecommuting programs increase employee morale and productivity. Employees save through reductions in expenses such as commuting, laundry, and meals but may also have increased expenses for additional home utilities and home work equipment. Studies by the state of California and the Southern California Association of Governments show the benefits exceeding the costs. The Phoenix study cited earlier concluded that the cost of a telecommunications program would be $15.38 per registered vehicle per year for additional computer equipment and that there would be a reduction in vehicle operating costs of $11.62 per vehicle per year, resulting in a net cost for the program of $3.76 per vehicle per year. An FHWA study suggests that the cost of additional computer equipment would be $350 per telecommute employee.

Widespread telecommuting programs are not yet common, but Los Angeles County government and California State government in Sacramento both have instituted programs.

COMPRESSED WORK WEEK

Employees participating in compressed work week programs work more hours per day and fewer days per week. The most common programs are referred to as 4/40 and 9/80 programs.
4/40 program, employees work four ten-hour days each week and have three days off. In the 9/80 program, employees work nine-hour days and get one extra day off every two weeks. As with telecommuting, not all jobs are suitable for compressed work weeks. School teacher positions would be an obvious example. The COMSIS Philadelphia study concluded that 9.7 percent of the jobs in the region were suitable for compressed work weeks.

These programs affect work trips in two ways. They reduce total work trips due to the extra days off, and, because of the longer work days, they move at least one end of work trips outside of the peak hour, which helps to reduce congestion. Unlike telecommuting, this TCM works as well for many manufacturing and service-sector jobs as for office workers. But it may reduce the ability of employees to participate in ridesharing programs or to use transit that is scheduled around traditional work schedules.

The costs of implementing these programs are primarily the expenses of administering the programs. The Phoenix study cited previously concluded that the cost of administering alternative work-hours programs amount to $0.88 per registered vehicle per year. There may be some increased utility costs at the work place due to the longer work day but there also are longer customer hours. There also may be some reduction in transit operating costs. Employee savings are the same as with telecommuting programs. There are numerous examples of compressed work week programs around the country, including one at CUTR and one for federal employees in Denver.

**FLEXIBLE WORK HOURS**

This program gives employees some flexibility in determining when to come to work and when to leave. Often this flexibility is used to avoid peak-hour traffic. It may also be used to coordinate better with ridesharing and transit schedules or just to have more leisure time in the afternoon. A typical program allows employees to start work any time between 7:00 a.m. and 9:00 a.m. and to leave work nine hours later, between 4:00 p.m. and 6:00 p.m.

To the extent trips are moved out of the peak hour, congestion is reduced. However, another consequence of spreading employee arrival times over a two-hour period is that ridesharing opportunities may be reduced. If transit service is oriented to the standard 8:00 a.m. to 5:00 p.m. workday, flexible hours may cause some transit users to switch back to their automobiles. Flextime policies, therefore, generally are considered to be less effective than compressed work weeks. The actual impacts of a program are, in part, a function of the amount of peak period congestion and how sharp the peak is. These programs work best for office workers and are less suitable for manufacturing and service-sector jobs.

Flextime programs are quite common. San Francisco had an area-wide demonstration program that covered the entire city. In the San Francisco program 2.3 percent of the workforce participated, and it was estimated that transit users saved six minutes per trip and that automobile
users saved nine minutes per trip. The costs of these programs are the same as for compressed work weeks, i.e., administration and increased office utilities. As noted above, the Phoenix study estimated the administrative cost for this type of program to be $0.88 per registered vehicle per year.

STAGGERED WORK HOURS

This program is very similar to the flexible work hours program. The primary difference is that employees have less flexibility in setting their start and stop times. This program is usually instituted in an attempt to reduce congestion in the vicinity of the work place, such as at a plant entrance. A typical program may have 20 percent of the employees scheduled to start at 7:00 a.m. and then 20 percent more each half hour until the final 20 percent start at 9:00 a.m. The program impacts are likely to be similar to the flextime impacts but perhaps not quite as great since employees have less flexibility in adjusting their travel patterns. The costs also would be similar.

TRAFFIC SIGNAL OPTIMIZATION

The purpose of improving the coordination and timing of traffic signals is to increase the efficiency of the existing road system. The result is increased speeds and reduced idling. But an improved traffic flow may draw more traffic, resulting in an increase in VMT and the number of trips and an increase in cold starts and hot soaks. Unlike some TCMs that are aimed primarily at peak-hour traffic, traffic signal coordination affects traffic all day.

A signal timing program in Sacramento resulted in a 10 percent increase in speed on the roads involved. An analysis in Philadelphia concluded that a 10 percent increase in speeds could be achieved on the affected arterials and a 6.5 percent increase in the CBD. Other studies suggest that travel time improvements of 10 to 25 percent are possible on the facilities involved. Signal coordination and timing is often a part of the ongoing transportation improvement program in urban areas. These programs are popular with the public and very practical. They are more expensive than some of the other TCMs, but less expensive than other options. One study suggests that, depending on the level of coordination involved, the cost of a signal timing program can range from $5,000 to $13,000 per traffic signal.

RIDESHARING

Ridesharing often is informally organized by friends or co-workers who decide to share a ride to work or to some other destination. Many area-wide ridesharing program were formally organized by local and state governments in the 1970s in response to the energy crisis. These large, formally organized programs have a staff that is responsible for promoting the program and matching
potential riders. There was a significant decline in ridesharing in the mid-1980s as gas prices dropped. Ridesharing has increased since then due to its extensive promotion as a TCM.

As with many TCMs, ridesharing’s impact is somewhat limited because it targets primarily work trips, which, according to the reports by Apogee and Cambridge Systematics, are only 25 to 33 percent of all trips in urban areas and 32 to 36 percent of VMT. Other types of trips, such as driving children to school, can also be targeted. In 1977, actual area-wide VMT reductions of between 0.05 percent and 0.28 percent were recorded for 15 different ridesharing programs. In 1978 the average cost per VMT reduced was estimated at 2.4 cents. It is estimated that over the past several years the ridesharing program in Hillsborough County has reduced VMT in a range of between 1,197,401 and 3,545,246 miles at a cost of $938,877, which would translate to be between 26.5 and 78.4 cents per VMT reduced.

Ridesharing programs are very common, existing in most urban areas. They usually are organized and promoted through a local commute management organization and operated through employers.

PARK-AND-RIDE LOTS

The intent of park-and-ride lots is to collect SOV drivers and transfer them to high-occupancy modes, such as ridesharing and transit. These parking lots need to be located so they can intercept vehicles before they enter congested areas; this can be on the CBD periphery or out in the suburbs. They can be dedicated lots or joint-use lots, such as a church parking lot. Usually there is either no parking fee or a very low one, so the costs of building and maintaining the lots are usually not recovered. Their success is, in large part, a function of the level of transit service.

The effect of park-and-ride lots is to move SOV trip ends (hot soak and cold start) out of congested CBDs. Moving cold starts from the CBD to suburban parking lots may reduce local concentrations of vehicle emissions but it is less effective in reducing area-wide emissions. The total number of trips generally is not reduced but VMT are reduced since SOV trips between the parking lots and downtown are replaced by fewer HOV trips. If services such as dry cleaning and day care are made available at the lots, some side trips can be eliminated. Bicycle storage facilities also can result in the elimination of some automobile trips. One study of park-and-ride facilities in several urban areas determined that 49 percent of the users previously had commuted to the CBDs in single-occupant-vehicles. Of the remaining users, 23 percent had previously been carpoolers and 10 percent had used transit; 15 percent of the trips were new trips. This study suggests that park-and-ride lots actually increase the number of cold starts. In part, this may be due to the fact that if there is high demand for limited CBD parking, park-and-ride lots can free up some CBD parking and induce new trips to the CBD, resulting in a net increase in cold starts.

There are numerous examples in Florida and around the country of park-and-ride lots. They are easy to implement, but they are costly. Surface parking typically costs $2,500 to $3,000 per
space. In Hillsborough County the cost has been somewhat less. A study of park-and-ride in Philadelphia used a cost of $4,000 per space excluding land costs and assumed an operating and maintenance cost of $0.50 per space per day. The Phoenix study calculated the cost of constructing park-and-ride lots minus the savings from reduced vehicle operating costs and arrived at a net cost for such a program of $5.77 per registered vehicle per year.

HILLSBOROUGH COUNTY IMPACTS

TCM impacts will vary among communities. Applying average results obtained in other communities to Hillsborough County will not give precise measurements, but should give reasonable orders of magnitude and relative effectiveness. It should also be noted that these estimates do not account for the maximum attainable under the most forceful implementation program. Rather, they reflect typical experiences in other regions.

To calculate the reduction in emissions in Hillsborough County, the county’s average combined emission rates per VMT of 0.01741 pounds of VOC and NO\textsubscript{x} was used. Also used was the trip-end emissions data calculated by Cambridge Systematics,\textsuperscript{44} which indicate that trip-end emissions account for 75 percent of all emissions on a 5-mile trip and 61 percent on a 10-mile trip. This suggests that, for the average 7.51-mile trip in Florida’s urban areas, trip-end emissions account for 68 percent of total emissions and VMT account for 32 percent. The calculations then give us estimated trip-end emissions for each trip of 0.08891 pounds combined of VOC and NO\textsubscript{x}. Each VMT is responsible for 0.00557 pounds of VOC and NO\textsubscript{x}. Therefore, total emissions for the average 9.19-mile “work” trip (by auto or van) in Florida’s urban areas are 0.14010 pounds of VOC and NO\textsubscript{x}. For the average 2.71-mile “other” trip in Florida’s urban areas the total emissions are 0.10401 pounds of VOC and NO\textsubscript{x}.

Parking Pricing

If Hillsborough County adopted a pricing policy that increased the daily parking rate in central business areas (i.e., downtown and Westshore) by $2.00 for work trips, Apogee’s analysis suggests that VOC emissions would be reduced 2.8 percent. Based on the $30,000 to $50,000 annual cost in Eugene and Santa Cruz to administer and enforce a parking pricing program,\textsuperscript{35} it is estimated that Hillsborough County could undertake such a program for no more than $500,000 per year (perhaps a generous assumption). If a proportional reduction in NO\textsubscript{x} is assured, this would result in a cost per ton of VOC and NO\textsubscript{x} eliminated of $431. However, this impact assumes that there are several good alternatives to the single-occupant automobile. In Hillsborough County, a likely result of this policy would be that many jobs would be relocated from the CBD to suburban areas, and the reduction in total trips would be significantly less than computed in the Apogee study.
Used in the appropriate location, parking pricing can be an effective TCM. However, parking pricing also is the least publicly acceptable TCM and in our view, Hillsborough County is not today an appropriate location for any significant application of such a program. Consequently, it is unlikely that it would be considered by local government in Hillsborough County in the foreseeable future.

**High-Occupancy-Vehicle Lanes**

HOV lanes are an effective TCM but they can be expensive. They also may be more effective in urban areas larger than the Tampa area. Apogee’s analysis suggests that if an extensive network of HOV lanes were constructed, in a typical large urban area, the area could expect a 1.1 percent reduction in VOC emissions at a cost of $109,000 per ton. If we assume that HOV lanes would be equally cost-effective in Hillsborough County, the cost of reducing VOC and NO\textsubscript{x} would be $50,629 per ton.

**Telecommuting**

Telecommuting and compressed work weeks may be the most effective TCMs that Hillsborough County could undertake, but perhaps not quite as effective as Apogee’s analysis suggests. Apogee’s assumption that 10 percent of the total workforce would telecommute two days per week seems optimistic. To calculate the effect in Hillsborough County findings from the COMSIS Philadelphia study were used, which estimated that 15.6 percent of the jobs in the region would be suitable for telecommuting. That percentage will vary, among regions and a local percentage could be calculated for Hillsborough County to refine the estimated impacts, but for this estimate the Philadelphia percentage is reasonable. A synthesis of national experience in the December 1992 ITE Journal states that on average if telecommuting is offered as an option, 32 percent of employees will telecommute 1.8 days per week. These percentages suggest that 5.0 percent (15.6 percent times 32 percent) of Hillsborough County’s workforce might telecommute. If it is assumed that 10 percent of employers (of persons in jobs suitable for telecommuting) will offer the option, 0.5 percent of Hillsborough’s workforce of 546,000 employees, or 2,730 employees will telecommute. If they telecommute 1.8 days per week for 50 weeks per year, that would be a reduction of 180 work trips per year per employee, or a total of 491,400 trips. Before calculating what emissions reduction will result from the reduction in trips, the fact that must first be taken into account is that some of those trips would have been made by transit and other non-SOV modes. Methodologies developed by the state of California use a factor of 0.85 to adjust for this. Multiplying the 491,400 trips by 0.85 gives a total reduction of 417,690 trips.

Using the emissions per 9.19-mile work trip calculated previously, yields a reduction in emissions of 29.26 tons of VOC and NO\textsubscript{x}. One final adjustment is necessary to account for new trips that telecommuters may make on the days that they are working at home. It was assumed that each telecommuter will make on average one-half new “other” round-trip each week for 50 weeks per
year. This will amount to 136,500 new 2.71-mile trips, which will increase emissions by 7.10 tons of VOC and NO\textsubscript{x}. The net reduction then is 22.16 tons of VOC and NO\textsubscript{x}. Not included here are emissions reductions that may result from an increase in the average speed due to reduced congestion.

If we assume that any costs for home computer equipment are borne privately and are offset by the benefits that individuals receive from telecommuting, the only costs of a telecommute program are the administrative costs. If an administrative cost of $20 per year per telecommute employee issued, which is approximately what was calculated by Sierra Research and Charles River Associates for Phoenix,\textsuperscript{58} the total cost for a county-wide telecommute program would be $54,600 per year and a cost of emissions reductions of $2,464 per ton.

**Compressed Work Week**

The calculation of the impacts of a compressed work week program is similar to the calculation for telecommuting. The COMSIS Philadelphia estimates that 9.7 percent of jobs are suitable for compressed work weeks and that if a 4/40 compressed work week program were offered 32 percent of employees would accept it are used. As with telecommuting, it is assumed that 10 percent of employers (of persons in jobs suitable for compressed work weeks) will offer the option. This would mean that a total of 1,695 employees would be participating in Hillsborough County. On a 4/40 program, this would result in 100 fewer work trips per year per employee (one extra day off per week for 50 weeks times two one-way trips per day) for a total reduction of 169,500 trips per year. Reducing this by the 0.85 factor explained in the telecommuting calculation gives us a reduction of 144,075 SOV trips per year.

The reductions in emissions for these 9.19-mile work trips are then calculated to be 10.09 tons of VOC and NO\textsubscript{x}. Next the same adjustment for new "other" trips was made for telecommuting, assuming that each employee on a compressed work week schedule would make on average one-half new "other" round-trip per week. These new trips would add 4.41 tons of VOC and NO\textsubscript{x}. The net reduction in emission would be 5.68 tons of VOC and NO\textsubscript{x}. As with telecommuting, reduced emissions due to increased average speeds are not included.

If an administrative cost of $20 per participant is used, total cost of $33,900 per year, which yields a cost of emissions reductions of $5,968 per ton.

**Flexible Work Hours and Staggered Work Hours**

To calculate the impacts of these two TCMs, the assumptions and results from JHK’s study of California’s San Joaquin Valley are used.\textsuperscript{59} That is, it is assumed that 2 percent of the workforce would participate in each of these programs and that this would result in a 0.11 percent reduction in VOC emissions attributable to each program. It is assumed that the same $20 administrative
cost is used for telecommuting and compressed work weeks. This results in 10,920 employees participating and emissions reductions of 21.19 tons of VOC.

At $20 per year per participant, the total cost of the program would be $218,400. If proportional reductions in NO\textsubscript{x} are assumed, the cost of the reductions is $4,787 per ton.

Traffic Signal Optimization

For this TCM, Apogee’s estimate that an extensive program of optimizing traffic signals would result in a 0.4 percent reduction in VOC emissions and that the cost of this reduction would be about $18,000 per ton was used. If a proportional reduction in NO\textsubscript{x} is assumed, the total cost per ton would be $8,360. However, it is important to note that in Hillsborough County programs for traffic signal optimization, ridesharing, and park-and-ride lots have been in place for many years. Therefore, these are not new programs that can be adopted to bring about new reductions in emissions; for the most part a substantial amount of the potential impacts of such programs has already been realized in Hillsborough County. These are ongoing programs and they can be expected to result in additional reductions in emissions, but not at the level for new programs estimated by Apogee, although for the sake of comparison the impacts for new programs were used. It is also important to note that congestion reduction benefits, such as reduced travel time, of these TCMs have not been factored into the emission-reduction cost calculations. In the case of traffic signal optimization, travel time savings can be significant and would likely result in net cost savings.

Ridesharing

Apogee estimates that an area-wide ridesharing program can result in a 0.4 percent reduction in VOC emissions at a cost of $16,000 per ton. Historically, Hillsborough County’s cost has been substantially higher. It has been estimated that at a cost of $938,877 the county’s ridesharing program has resulted in VMT reductions between 1,197,401 and 3,545,246 VMT. If the highest of these estimates and the county’s average emission rates per VMT are used, the costs of VOC and NO\textsubscript{x} reductions attributable to the ridesharing program are calculated as $30,424 per ton.

Park-and-Ride Lots

Apogee estimates that an extensive park-and-ride program can result in a 0.3 percent reduction in VOC emissions at a cost of $146,000 per ton. However, Apogee used a cost per park-and-ride space of $10,000, while Hillsborough County’s experience is more like $2,000 per space. Adjusting this by dividing Apogee’s cost figure by five yields an emissions reduction cost of $29,200 per ton. If a proportional reduction in NO\textsubscript{x} is assumed, there is a reduction cost of $13,563 per ton.
As suggested previously, Hillsborough County has numerous park-and-ride lots in place and there does not appear to be a substantial unmet demand for such lots.

COST EFFECTIVENESS OF TCMs

This report does not address the question of whether or not local government should implement or encourage the implementation of transportation control measures. That decision should be based on an analysis of the complete costs and benefits of each TCM. Those benefits include reductions in traffic congestion as well as reductions in vehicle emissions. This report looks only at the question of how effective TCMs are in reducing vehicle emissions. It does not consider their relative effectiveness in reducing congestion.

Other than parking pricing, the TCMs that are most cost effective in reducing emissions are those that involve modifications in employees’ work schedules. Telecommuting, compressed flexible or staggered work hours and compressed work week all appear to be significantly more cost effective than the other TCMs. Although less cost-effective, traffic signal optimization, park-and-ride lots, and ridesharing are TCM programs that are already in place in Hillsborough County and are contributing to emissions reduction. As noted previously, parking pricing probably is not an appropriate TCM to implement in Hillsborough County, primarily because of public opposition and the negative impact it might have on economic development in Tampa’s central business district. Any decision to construct HOV lanes probably should be based on merits other than their cost effectiveness in reducing emissions.

It also should be noted that combinations of TCMs may result in greater or lesser impacts than the total of the individual impacts. For example, HOV lanes and ridesharing are synergistic, while staggered work hours will reduce the effectiveness of ridesharing.

This analysis suggest as part of an overall air quality improvement program, local government should promote the implementation of telecommuting, flexible or staggered work hours, and compressed work weeks. However, as shown in Table 14, the actual amount of emissions these TCMs eliminate is relatively small. If it becomes necessary or desirable to use TCMs to eliminate larger amounts of emissions, it will be necessary to go to more aggressive TCMs, such as parking pricing, or to more costly TCMs.
### Table 14
Annual Cost of Using TCMs to Reduce Emissions

<table>
<thead>
<tr>
<th>TCM</th>
<th>Tons of VOC and NOx Eliminated</th>
<th>Annual Cost</th>
<th>Cost per Ton</th>
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<td>Parking pricing</td>
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<td>Staggered work hours</td>
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<td>Park-and-ride lots</td>
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<td>Ridesharing</td>
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<td>HOV lanes</td>
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</tbody>
</table>

1 If the positive benefits of travel time savings were included, traffic signal optimization would probably show as net benefit.

2 Tons and total cost for ridesharing are for several years.
VI. CONCLUSIONS

As indicated in the previous sections, TCMs are not generally as cost-effective as emission inspection programs. In addition, the scale of their impact is modest, at best. There are two notable exceptions. Parking surcharges, which can be effective, are likely to be politically unacceptable. Considering the policy implications on downtown development, we are not prepared to recommend widespread implementation of parking surcharges. Traffic flow improvements can be cost-effective because of their travel time savings benefits, though the scale of their impact on air quality is modest.

On the other hand, motor vehicle inspection programs are generally cost-effective and they achieve substantial reductions in pollutant emissions. This is particularly true for enhanced inspection and maintenance programs such as IM240 and ASM. Because of the reported high level of effectiveness of IM240 and ASM, inspection requirements can be reduced to every other year. Furthermore, due to the very low failure rates for late model year vehicles, it is recommended to exempt the most recent three model years from the inspection requirement.

Based on a consideration of the cost effectiveness and the absolute impact of various alternatives, we have come to the following conclusions:

• Motor vehicle inspection programs yield substantial reductions in mobile source emissions.

• Motor vehicle inspection programs are comparatively cost-effective.

• Although many TCMs are good public policy, as they reduce congestion and improve the efficiency of the transportation system, their impact on mobile source emissions is likely to be modest.

• Florida should continue its program of motor vehicle emission inspections, with the following features:
  • ASM as the basic inspection method, with inclusion of a pressure test.
  • Centralized inspection, with provision for certification of remote reinspection sites at service stations and repair shops.
  • Biennial inspection.
  • Exemption of vehicles of the current model year, as well as the two preceding model years.
  • A mobile roadside testing program to serve as a countermeasure to vehicle tampering.
• The Florida Department of Environmental Protection and local air quality agencies should continue to monitor ambient air quality, as well as to update emissions inventories. Based on future conditions, it may become necessary to consider a more stringent test, such as IM240, at some time in the future.

• The Florida Department of Environmental Protection and Department of Highway Safety and Motor Vehicles should continue to monitor emerging motor vehicle inspection technologies.

This combination of program elements can achieve substantial emission reductions cost-effectively and with minimal intrusion into personal lifestyles.
VII. ENDNOTES


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